

Innovation in a strategic development program: the Aerospace Program in Brazil*

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ABSTRACT

This paper presents a case of strategic technology development in Brazil, analyzed under the framework of open innovation. Here examined, the aerospace sector is an area of high technology which has strategic importance to this country. By analyzing this specific development program as a case study, a network with links between public and private institutions was identified. Specific issues such as business aspects, funding, intellectual property, technological trends, and coordination of the group of firms and institutions at the interorganizational level are discussed and alternatives for the network are proposed. Main results indicate that there is a network, and the open innovation approach may help to increase awareness of and help clarify intellectual property issues. The analysis revealed this may be a significant bottleneck, along with funding issues and scarcity of qualified human resources.

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KEYWORDS | Open Innovation; Aerospace Applications; Interorganizational Network; Intellectual Property

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**Inovação em um programa estratégico de desenvolvimento:
o programa espacial brasileiro**

RESUMO

Este artigo apresenta um caso de desenvolvimento estratégico de tecnologia no Brasil, analisado sob a teoria da inovação aberta. Uma área de alta tecnologia de importância estratégica para o país, o setor aeroespacial, constitui o objeto de análise do presente artigo. Ao abordar esse programa específico como um estudo de caso, foi identificada uma rede com ligações entre instituições públicas e privadas. São discutidos temas específicos, como negócios, financiamento, propriedade intelectual, tendências tecnológicas e coordenação do grupo de instituições em empresas ao nível interorganizacional, e propostas alternativas para essa rede. Os principais resultados indicam que existe uma rede e que a abordagem da inovação aberta pode contribuir para melhorar a conscientização sobre assuntos ligados à propriedade intelectual, revelado pela análise como sendo um gargalo importante, além mitigar problemas relacionados a financiamento e escassez de recursos humanos qualificados para o setor.

PALAVRAS-CHAVE | Inovação Aberta; Aeroespacial; Rede Interorganizacional; Propriedade Intelectual

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1. Introduction

The number of empirical studies using open innovation frameworks has been growing in the last couple of years. However, studies concerning technological and managerial challenges through this perspective in developing countries are still scarce in the international literature. This paper presents a case of strategic technology development in Brazil, analyzed under the framework of open innovation. The aim was to study, in this context, competence development in an area of high technology which is strategic to the country, namely the aerospace sector. It is strategic because components such as integrated circuits for satellite applications may suffer international commercial restrictions, and must be developed internally, thus the motivation for addressing their complete development cycle, analyzing how this affects relations between different participating institutions, both public and private, leading to focused development of resources which are necessary to enhance the space program and to develop critical products.

The aerospace industry draws its high technology components from the electronics sector. In Brazil, this sector has a historical trade balance deficit, which in 2008 reached US\$ 3.426,7 million in integrated circuits alone. However, this number does not reflect the entire deficit of the electronic industry, because imported electronic goods and whole or parts of equipment with embedded semiconductors are not computed (GUTIERREZ; MENDES, 2009).

We address issues about open innovation practices in the network. Given the specific institutional environment, how is it structured, organized and managed? It seems relevant to investigate its main difficulties and weaknesses, concerning the issues mentioned above.

The Brazilian aerospace program may act as a mechanism to foster open innovation among participating companies, establishing links with universities and research institutions to solve technological problems. In this context, the open innovation framework seems useful for an analysis of the network's development to be conducted, in which many complementary competencies, available in different institutions throughout the country, need to be coordinated, with the objective of building competencies in Brazil in the complete development cycle of integrated circuits for aerospace applications (specification, design, simulation, layout, manufacturing, encapsulation, test, and qualification). By analyzing this specific development program as a case study, we hope to identify links between institutions. Specific issues which constitute gaps in the current literature on open innovation,

concerning business aspects, funding, intellectual property (IP), technological trends, and coordination at the interorganizational level are discussed, and alternatives for the network are proposed.

Our research question is about open innovation practices in the network. Given the specific institutional environment, how it should be managed? It is important to investigate the main difficulties and weaknesses of the studied network, concerning the issues mentioned above.

Beyond the main purposes presented, this research explores the role of the geographic location in the innovation process. Geographic location of innovation has been studied, from a firm's perspective, the types of networks that influence their search for university partners are geographically proximate social networks (JAFFE, 1989; OWEN-SMITH; POWELL, 2004). Its implication for open innovation has been developed by Simard and West (2006). As discussed by the authors cited above, it seems that the geographical proximity of many institutions participating in the aerospace program can influence both formal and informal exchanges of knowledge.

The article is organized in five sections. Section 2 is dedicated to discuss the theoretical foundations of open innovation and how it is linked to issues of interorganizational relationships and intellectual property. Section 3 presents the method used in this research. Section 4 presents an overview of the Brazilian aerospace industry. Section 5 characterizes and analyzes the network of institutions in the Brazilian aerospace industry. Section 6 is dedicated to present the concluding remarks and managerial implications.

2. Theoretical assumptions

2.1. Open innovation and interorganizational relationships

In the last few years, innovation studies have emphasized the growing relevance of external sources of innovation. The paradigm of open innovation suggests that valuable ideas may occur either inside or outside the company, giving similar importance to external ideas and means to market as to internal ideas and channels to market (CHESBROUGH, 2003).

The role of interorganizational relationships in a context of open innovation has emerged as a relevant field of research in the last couple of years (VANHAVERBEKE, 2006; VANHAVERBEKE; CLOODT, 2006). Interorganizational relationships and

networking are crucial dimensions of open innovation (VANHAVERBEKE, 2006, p. 210). It is pointed out that the interorganizational network is one of the levels of analysis, when open innovation is no longer studied at single company or dyad level. A company's relationships, depending on which sector it belongs to, usually play a very important role in its strategy and in the way it is managed over time. It is the embedded character of relationships between companies inside networks that leads to the formation of more complex topologies.

Rather than relying on internal R&D, organizations are reported to increasingly engage in 'open innovation' (CHESBROUGH, 2006). This means that innovation may be considered as resulting from distributed interorganizational networks, rather than from single firms (POWELL et al., 1996; COOMBS et al., 2003). In the same direction, various concepts of 'interactive' innovation have been presented to understand the non-linear, iterative and multi-agent character of innovation processes (KLINE, 1985; LUNDVALL, 1988; VON HIPPEL 1988).

Almost by definition, open innovation occurs through the establishment of links between innovative firms with other institutions, being another way to analyze innovative behavior of firms. Analyzing the interorganizational context of open innovation, organizations are urged to collaborate with others to develop or absorb new technologies, sell new products, or simply keep up with the latest technological advances (VANHAVERBEKE, 2006). High costs and uncertainty in knowledge creation are powerful reasons to explain why firms frequently resort to external sources of ideas (VON HIPPEL, 1988). Research on innovation emphasizes the role of the firm's external dimension as an important locus of useful knowledge (ARORA; GAMBARDELLA, 1990; CALOGHIROU et al., 2004; CASSIMAN; VEUGELERS, 2006; LICHTENTHALER, 2008). Such interfirm networks may offer flexibility, speed, innovation, and the ability to easily adapt to changes in market conditions and to new strategic opportunities (DITTRICH; DUYSTERS, 2007).

Cooperation networks have the capacity to facilitate joint actions and resource transactions to reach organizational goals. They may be defined as the set of repeated transactions which are supported by relational and structural configurations, possessing dynamic limits and interconnected elements (TODEVA, 2006). Cooperation networks constitute therefore a phenomenon which is present in organizational theory, and has thus been repeatedly studied from different theoretical approaches (GRANDORI; SODA, 1995).

Learning how to create and capture value when organizations are highly dependent on one another is an under-explored field in network literature. Most firms are accustomed to make decisions inside their limits, considering the external environment literally as an exogenous variable or as a locus in which firms compete with each other. However, in networks, value is produced together: total value created in the network depends directly on how well partners' objectives are aligned and on their commitment to invest in complementary assets (VANHAVERBEKE, 2006). In a similar way, in developing systemic technologies, an innovative firm depends on other firms' technological abilities and commitment. Many firms are not at ease in these open scenarios where earnings fundamentally depend on partners (MAULA et al., 2006).

The establishment of cooperative networks seems to be important in processes related to both technological complexities, to make innovation possible in manufacturing firms, and also due to the increasingly global nature of markets and economies, which results in a global division of labor and in a more intense competition (ÁLVAREZ et al., 2009). According to these authors, motivations for cooperation are grouped into two: the complexity of technological development and the uncertain and costly nature of research, as well as market access and search for opportunity.

Cooperation is a potential way to transfer tacit and specific knowledge, through close links between different organizations (CALOGHIROU et al., 2004). Small and medium industrial firms, as well as multinationals, are building closer relationships with other firms to obtain larger economies of scale, market share or to explore new opportunities. They engage formally and informally in joint activities such as co-marketing, co-production, resource sharing or co-development. In the dynamic capabilities approach, Teece et al. (1997) consider cooperation as a mechanism through which firms accumulate and combine knowledge and other complementary assets.

Finally, the open innovation hypothesis may serve as a useful reference point for guiding research considering the organizational dynamics of collaboration arrangements between universities, industry and government, which has been introduced by Etzkowitz and Leydesdorff (1998; 2000) with the Triple Helix approach, but remains under-researched in terms of its effect on the innovation process (PERKMANN; WALSH, 2007).

2.2. Intellectual property

Economic systems and institutions such as the protection of intellectual property (IP) rights may have significant effects on the behavior of firms with respect to their engagement in open innovation practices (SAVITSKAYA et al., 2010).

An IP policy for a network is a challenging arrangement. Multiple parties have different interests that must come into balance. By defining property rights, IP helps to enable exchange of ideas and technologies between the many parties who possess useful knowledge (CHESBROUGH et al., 2006). Concerning participation of universities, bi-directional channels of knowledge flows offer the possibility to yield innovative and productive benefits for firms and intellectual and economic benefits (FERNANDES et al., 2010).

In the open innovation paradigm, changes in the general role of IP are being observed, particularly in patenting practices. This may be attributed to technological changes, in which they cease to be the only source of value capturing to firms. Value creation may occur, for example, through the generation of open standards (SIMCOE, 2006), in a cooperative fashion, removing emphasis of a patent as the sole mechanism of competitive advantage. According to Giannopoulou et al. (2010), in this paradigm, it has become evident that, where collaborations are established, IP has begun to be proactively shared, although such assets may still be used in a defensive way by some companies.

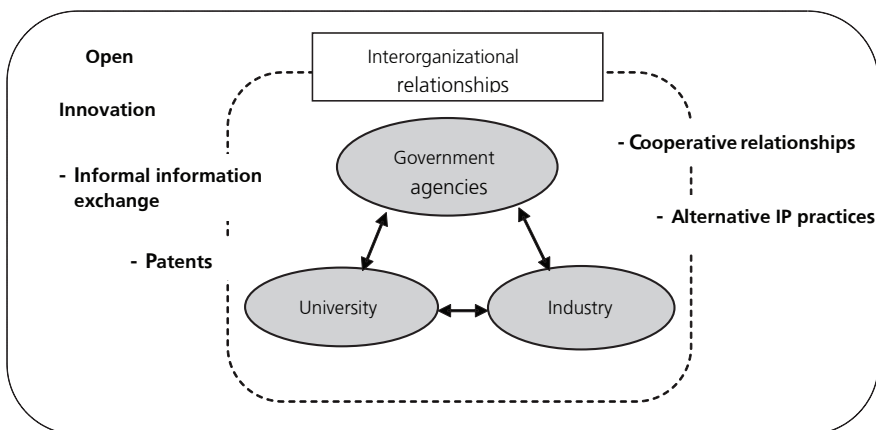
Based on a survey among industrial R&D executives, Cohen et al. (2002) distinguish between the following channels relevant to industrial innovation: patents, informal information exchange, publications and reports, public meetings and conferences, recently hired graduates, licenses, joint or co-operative research ventures, contract research, consulting, and temporary personnel exchanges. It is argued that in contexts of open and networked innovation, interorganizational relationships between public research organizations and industry play an important role in driving innovation processes. Specifically, it appears that the contribution of relationships to innovative activities in the commercial sector considerably exceeds the contribution of IP transfer (e.g. licensing) (PERKMANN; WALSH, 2007). Slowinski and Zerby (2008) approach the challenges that arise regarding IP in collaborations between companies; for instance on how to apply for patents when they derive from a collective invention.

In universities, patenting is a minor activity; a majority of the faculty in one sample never patent, and publication rates outnumber patenting rates by far as mechanisms of knowledge spilling out of the university (AGRAWAL; HENDERSON, 2002). Others conclude that openness is associated with a moderate level of appropriability through IP rights; therefore, depending on the industrial sector, patents and university research may play a larger or smaller role in innovation (LAURSEN; SALTER, 2006). In this direction, potentially negative impacts of high appropriability upon the cumulative and decentralized aspects of open innovation are identified (CHESBROUGH et al. 2006; FABRIZIO, 2006), with several concerns as to the potential of limited availability of university research and the destruction of norms that support the cumulative, open nature of scientific discovery associated with university research.

It is said that IP rights are far from the entire solution to inadequate innovation in developing countries, independent of the specifics of the particular IP regime (GREENBAUM, 2009). Policy makers have to consider greater overall economic, infrastructural and cultural hurdles to increased science and innovation. Although IP issues are crucial for open innovation, there is a lack of effective IP management practices in the literature. This is a topic that requires more attention as it is one of the major barriers to open innovation (GIANNOPOULOU et al., 2010), especially in a context of collaboration between different kinds of organizations.

Considering the theoretical arguments presented, we propose an analytical structure for this paper (shown in Figure 1).

FIGURE 1
Analytical structure



3. Research method and data analysis

The method employed in this article was a single case study of an interorganizational network, which constitutes the level of analysis (VANHAVERBEKE, 2006). Case studies are recommended as a research method when knowledge in a certain field is comparably limited and new, and also when there is need to retain richness of the studied incident in its context (EISENHARDT, 1989; YIN, 2003).

The presented case, the aerospace industry cluster concentrated in and around São José dos Campos, a city in the State of São Paulo, Brazil, is a network of companies, universities, and research institutions. It has the special characteristic of combining various types of both public and private organizations around a specific high technology industrial segment. This makes it a unique setting to conduct research in open innovation practices, because of the need to focus on development of complementary resources to manufacture critical components locally, which may suffer commercial restrictions from foreign countries.

Data was collected in October 2009, and consisted of direct observation of the presentations and also interviews (total of seven) with a key representative from each of the following organizations: the Brazilian Space Agency, the industrial association, two federal research institutions, one design house, two universities, and the Ministry of Science and Technology. All these organizations are described in the sector overview in the following subsection. Research questions were related to business and technology aspects, what are the sources for innovative ideas, cooperative relations – formal or informal, funding, IP, technological trends, and coordination of the group at the interorganizational level. Additional data were collected through interviews with CEO's from three companies which are part of the network. Queries in official sources, such as the National Program of Space Activities document (AEB, 2005), sector reports, and websites of the participating institutions provided complementary information about innovation practices.

Data was analyzed based on the analytical structure proposed in section 2.

4. Findings: sector overview

The following subsection presents an overview of different points of view supported by the main actors in the Brazilian space sector, considering national strategic affairs, the industrial sector, technology, and business issues. The aim is to establish how each actor of the network should participate and contribute to

achieve the objectives discussed at the workshop held in São José dos Campos, State of São Paulo.

The Brazilian Space Program started in 1979, with the Complete Brazilian Space Mission (MECB). The satellites developed under this program were SCD-1 and 2 (Data Collecting Satellite), launched in 1993 and 1998, respectively. In addition, Brazil and China signed, in 1988, an agreement to cooperate for the development of the so-called Chinese-Brazilian Earth Resource Satellite (CBERS), which generates images of the Earth.

Three other satellites are being developed by INPE (National Institute for Space Research), which is responsible for the projects: the *Amazonia-1*, which shall be used to generate images of the Amazon region, *Sabia-mar*, developed in cooperation with Argentina, and *GPM-Brasil*, for meteorological studies.

The Brazilian space industry has two satellite launching programs under development, which will offer launching services to the market. In the satellite segment, the country does not yet have a communications satellite development program. There are, however, competencies in equipment and subsystems. In the services segment, there are more than 30 communication satellites supplying the Brazilian market. Brazilian companies operate around 10 satellites.

4.1. Brazilian aerospace institutions

4.1.1. Research institutions

The two main institutions for aerospace science and technology in Brazil are DCTA (Aerospace Science and Technology Department) and INPE.

DCTA was created in the 1950s, as CTA (Centro Técnico Aeroespacial) in São José dos Campos (São Paulo State). It has the role of building competences in aeronautics and aerospace. DCTA comprises ITA (Aeronautics Technology Institute), IAE (Institute for Space Activities), and IEAv (Institute for Advanced Studies). ITA offers graduate and undergraduate courses and research and extension activities in areas of interest to the Brazilian Air Force and the aerospace sector in general. IEAv, created thirty years ago, responds for pure and applied science and also technological development in various fields related to aerospace. IAE, in addition to development of missiles, is responsible for developing satellite launch vehicles (DCTA, 2009).

The other very important research institute for space, astronomy, meteorology, and related areas in Brazil is INPE, in São José dos Campos, State of São

Paulo. The institute was created in 1971, from the Group for the Organization of National Space Activities Commission, the institute's embryo, which had been created in 1961. It conducts research and development in the following areas: space and atmospheric sciences; weather forecast and climate studies; space engineering and technology; earth observation; satellite tracking and control; integration and testing laboratory. It works with associated laboratories in the fields of sensors and materials, plasma, computing and applied mathematics, combustion, and propulsion.

INPE is the executive organization for satellite and payload projects and applications, as well as for the establishment of operational and maintenance activities regarding the infrastructure associated to development, integration, tests, satellite tracking and control, and reception, processing and distribution of satellite data. INPE is also responsible for the coordination and implementation of research and development activities in the domains of science and space applications as well as satellite and payload technologies and associated domains. It is thus the main client in Brazil for radiation resistant components applied to the national satellite program, which supplied a satisfactory indicator of the R&D needs for such components, and their qualification for space environment (INPE, 2009).

Government Agencies

AEB, the Brazilian Space Agency, was created in 1994, with the responsibility of formulating and coordinating national space policy. It is a federal authority under the Ministry of Science and Technology, and has strategically contributed to the efforts undertaken by the Brazilian government to promote autonomy in the space sector since 1961. It is responsible for the National Space Activities Program (PNAE – 2005-2014). In order to face the technological challenges involved in large scale projects, PNAE is configured as an innovation fostering agent. R&D activities, with support of the academic community, play a fundamental role towards leveraging national industrial capacity and competitiveness, through the acquisition of strategic capacities and technology, new work processes and methodologies, in compliance with international quality standards. In the view of AEB, this knowledge shall lead to modernization and leveraging of Brazil's entire productive sector, through technology absorption mechanisms.

The agency also dedicates attention to international cooperation, which is an important mechanism for building technological capacity in the space sector. Agree-

ements have been signed with nine countries and one international organization for cooperation on peaceful use of outer space. These agreements lead to new bilateral space programs and eventually to the obtainment of new technologies (AEB, 2005).

Financial support for the government's industrial policy is given mainly by BNDES (Brazilian Economic and Social Development Bank), the country's largest investment bank, founded in 1952. Among its objectives is fostering competitiveness and technological innovation of the electronics industry in Brazil, thus establishing links mainly to private companies and with AEB for establishing funding guidelines for the sector.

4.1.2. Companies

Companies participating in the network vary in size and age, ranging from thirty to about 450 employees; the oldest company was established in the 1980s, and the others were established during the 1990s in the electronics, avionic and space industries, working with both civil and military clients. Their names were omitted upon request. All are located in the state of São Paulo, and have strong ties to universities and research institutions located in the same region. This is a main competitive advantage, for they benefit from highly qualified professionals who seek jobs in the region. They have common research-based origins (as high tech start-ups), since all were created by former researchers. All reported to have either formal or informal cooperative relationships with electronic component manufacturers and with Brazilian space institutions such as AEB, INPE and DCTA, and their international counterparts such as NASA (National Aeronautics and Space Administration), ESA (European Space Agency), CNES (French government space agency), and ISRO (Indian Space Research Organization). One of the companies has participation of EADS Astrium, the largest European company in the aerospace and defense sectors, as shareholder.

The Association of Aerospace Industries of Brazil (AIAB) is the national entity which represents companies in the Brazilian aerospace sector (aeronautics, space, and defense). Founded on March, 18, 1993, with headquarters in São José dos Campos, São Paulo, it operates similarly to associations in other countries. It is member of the International Coordinating Council of Aerospace Industries Associations, together with its counterparts from Canada, United States, and Japan.

Analogous to the aviation market, the position of AIAB is that it should strive to reach significant participation in the space market. It participates in the segments of ground equipment, mainly DTV, GPS, and other telecommunication

satellite equipment. Great demand is foreseen for HDTV, internet access, GPS, and maps (GIS).

According to AIAB, “the most innovative companies – the small and medium sized contractors – are among those that most suffered damage by exportation rules. They do not have enough resources or legal expertise to navigate the labyrinth of bureaucracy or to withstand manufacturing delays while waiting out the often lengthy ITAR (International Traffic in Arms Regulations) approval process” (AIAB, 2009).

The possible solutions to this problem would be to develop local suppliers and component qualification in Brazil, such as dedicated electronic module design (ASIC), module manufacturing on demand, and module qualification for space use (especially radiation). Other problems persist, even when ITAR obstacles are overcome, such as restrictions as to where to launch the satellite, limiting the alternatives and consequently elevating the costs, which impacts competitiveness. (AIAB, 2009).

According to one of the CEOs interviewed, companies in the Brazilian space sector seek ideas for products and applications in foreign space programs, developed by also foreign companies. Future trends for space technology in Brazil indicate that the role of public space research institutions in Brazil must change radically and urgently. These are excessively verticalized, competing with companies in certain areas. Brazilian aerospace science and technology institutions seem to encounter difficulties in transferring technology to companies, so that they may acquire capabilities to compete in the market. On the other hand, the research institutions are very large, absorbing a great part of available qualified human resources to maintain their structure. Not much goes to innovative development. When there is need for recruitment, as is the case of the CBERS Program mentioned above, it is partially through specification and basic project conducted at the research institutions, without considering the companies’ technological culture, determining the deployment of obsolete technology (because of the basic project) and by taking on part of the project such as purchasing components. The projects also suffer considerable development delays.

In the CEO’s opinion, research institutions should specialize in defining mission prerequisites and contracting companies to conceive, develop, and implement the program. In this way, companies would have more freedom and flexibility to search for the best alternatives with lower costs, establishing important partnerships to perform in the global market. To date, these research institutions do not use other institutions in Brazil, such as universities, to attain R&D objectives. They aim to do it internally, and, when not successful, technology is then acquired from foreign companies or institutions.

4.1.3. Universities

In addition to ITA, Brazilian universities, both public and private, have expertise and generate new knowledge in many areas related to aerospace science and technology, participating in the main international conferences and publishing research papers in international journals. There is a specific undergraduate course in aerospace engineering, in a state university in São Paulo. There are also active research groups in some universities working with the effects of ionizing radiation on electronic components, in electrical engineering and informatics departments.

4.1.4. Design houses

In March 2004, the Brazilian government launched an industrial policy program (CI Brasil) which had the aim to support microelectronics, among other industrial sectors. Design houses for integrated circuits were among the organizations to be fostered by this policy, and they should be directed in either of two strategies: linked either to Brazilian technological institutions or to multinational companies in the sector. Brazilian industry would be the potential client for the services of design houses (Gutierrez and Mendes, 2009).

In the context of CI-Brasil, the mission to start organizing the development of the aerospace market niche in Brazilian design houses was delegated to CTI (Center for Information Technology), especially for building competences in designing radiation-hard components, following strict international standards (FINCO, 2009). CTI has a design house (CTI-DH) with 40 employees, offering consulting services in microsystems design and manufacturing; design, prototyping, and production of electronic components and systems, and of analogical (ASIC), digital, RF, and mixed-signal integrated circuits; as well as qualified IP production for the global market, with application in wireless products, sensor networks, automotive, consumer electronics, among others. CTI as a whole is a R&D unit for information technology of the Ministry of Science and Technology, founded in 1982 in Campinas, São Paulo. It interacts intensely with academic and industrial sectors through research cooperation agreements. It has 10 laboratories dedicated to electronic components, microelectronics, systems, software, and IT applications, and almost 300 employees. The largest state funded design house in Brazil is CEITEC,¹ located in Porto Alegre

1 CEITEC: *Centro Nacional de Tecnologia Eletrônica Avançada*, a state-funded electronics technology company, created in 2008, works with development and manufacturing of integrated circuits.

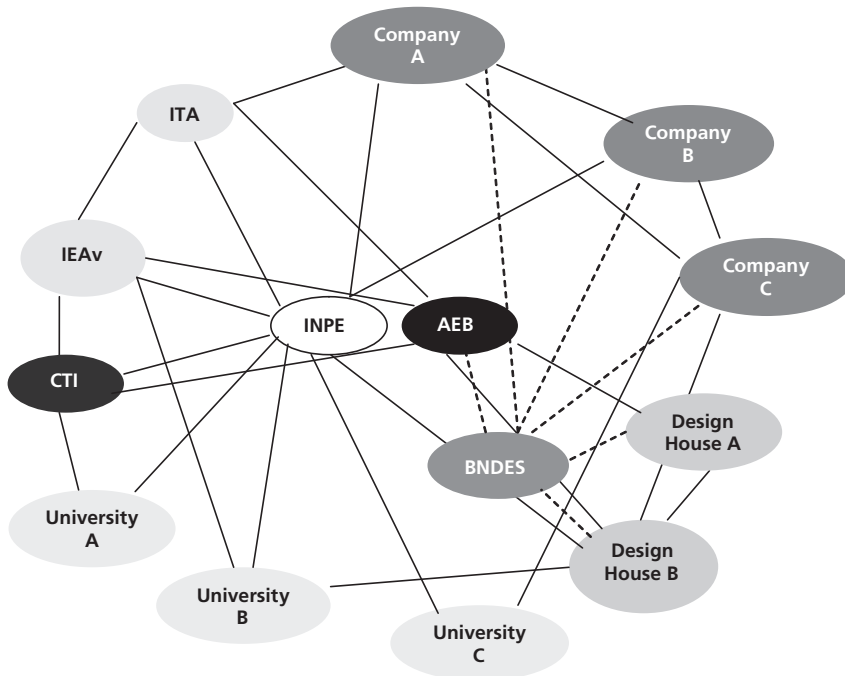
(south of Brazil), with almost 100 collaborators. It also has a production facility. There are over 10 other design houses distributed throughout Brazil.

5. Findings: the network of institutions in the aerospace industry

5.1. The network

Figure 2 shows the links in the network of institutions which participate in the aerospace industry. It should be noted that INPE and AEB play a central role, according to their characteristics, as discussed earlier in this section, and have links to almost all other institutions. As it is an illustration, universities, companies and design houses are shown without identification and in smaller number than those which actually participate in the network. BNDES establishes links mainly to companies and design houses and with AEB for funding guidelines for the industrial sector (expressed by the dotted lines).

FIGURE 2
Network of institutions in the aerospace industry in Brazil



This network of institutions took part of the II Workshop on Radiation Effects on Integrated Circuits, as mentioned above. The proposed objectives of this workshop were:

- disseminate knowledge on the effect of ionizing radiation on components and materials of aerospace interest;
- promote integration between policy and funding institutions, research institutions and companies in the aerospace sector, showing their visions, actions, needs, and perspectives as to the application of electronic and photonic radiation resistant devices in the Brazilian space program;
- identify short term demands (2 to 4 years) for R&D on ionizing radiation effects on electronic and photonic devices, aiming satellite applications;
- foster the creation of workgroups and a national network of institutions for studying the radiation effects on materials and devices, their qualification for space applications, and for the development of specific radiation resistant components with Brazilian technology.

These objectives suggest that a strategic management approach should be followed by the sector, if it wishes to become technologically independent. Other examples in Brazil, such as deep sea oil drilling, have succeeded in developing critical industrial technology, leading the country to become technologically independent. In this case, there was a government-led movement to foster development in the country, fed by public and private funding of the whole sector, with the leadership of Petrobras.

The first of the objectives listed above was achieved by organizing short courses on subjects pointed out by the participants of the first workshop. To meet the second and third objectives, representatives from the Ministry of Science and Technology, BNDES, AEB, and Defense (DCTA) were invited to explain the views of the major policy and funding institutions for the sector, as well as the main expectations and initiatives of the research institutions on radiation tolerant components for space applications. In this session, presentations of AIAB and INPE were included, the latter as the main applicant for radiation tolerant components for the national satellite program. This offered a satisfactory indicator of R&D needs for such components and their qualification for use in space.

In this way, participants were able to have direct contact with the sector's concerns, objectives and necessities related to the aerospace sector. Moreover, they were able to give precise and valuable orientation on how the community may organize itself to fulfill the fourth objective. This objective is very broad, and should start

with the organization of workgroups. The first step in this direction was a set of presentations of all present companies, universities, research institutes, and design houses, involved in the creation of integrated circuits for the aerospace market, focusing on its achievements in the area, involvement with research or problems concerning the radiation effects with which the institution is confronted, as well as competences and needs. These presentations enabled a favorable environment for:

- promoting collaboration and partnership between universities, research institutions, and companies;
- identifying and consolidating common necessities and ways of seeking support with official funding bodies;
- discussing strategic guideline propositions for the sector;
- evaluating the feasibility of workgroups to study future action.

The next step was to create groups to discuss and to propose strategies for the sector. It was established that the workgroups would be formed to continue discussions on common interests after the workshop. A suggestion of five different groups was given:

- specification group;
- design group;
- fabrication and encapsulation group;
- radiation robustness tests group;
- business group (funding sources and IP).

This proposal was accepted, and the objective of the business group was established to include identification of contact areas with the aerospace sector; funding alternatives which would permit the creation of conditions to meet the needs of the Brazilian space industry in the context of robust components; search for justification for the proposed developments and possible impacts in other areas of interest to the country. One of the group's main concerns is to survey problems and strategic solution proposals related to IP.

By analyzing the case, it is possible to identify that there is a network, although it has been working predominantly on an informal basis until now. There are important collaborative research agreements in place, however. Another difficulty is that Brazilian aerospace science and technology institutions have difficulties in transferring technology to companies, although they are aware of its importance, so that they may help companies to acquire capabilities to compete in the market. These institutions are very large, absorbing almost all human resources to maintain their structure. Not much goes to innovative development. As suggested in the

literature, in the scenario of technological complexity of the aerospace industry, cooperation is increasingly sought as a viable alternative for achieving competitiveness and overcoming gaps in innovation capacity.

The open innovation approach, however, remains theoretical, and not all participants are aware of it. This constitutes a difficulty to be overcome, if the aerospace sector is to be developed with competitiveness. It seems relevant to propose some recommendations to overcome the problems identified.

5.2. Technological and business issues in the space program

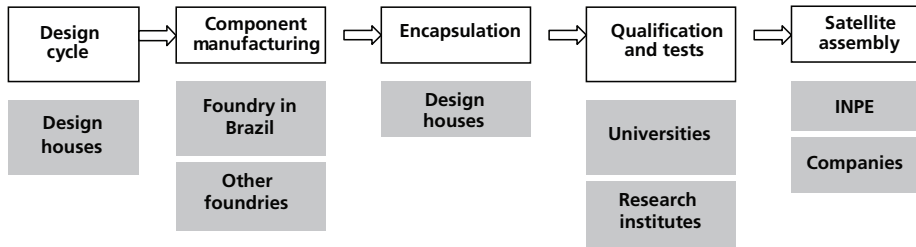
To further advance in the proposed developments, according to the Brazilian Space Agency (AEB), the Space Activities Program (PNAE) must be reviewed on topics such as putting more emphasis on a program orientation and building a catalogue of critical technologies. Radiation hardening, as such a critical technology, should be considered in the development cycle of integrated circuits. As stated by the interviewees, 10% of the cost of digital integrated circuits comes from specification, design (“soft” and silicon design, with many verification steps), manufacturing (with specific “radhard” processes), encapsulation, qualification, and tests. Considering the necessary investments in time and money, appropriate technological routes must be defined, focusing on increasing scale by reusing shared modules. Other challenges include planning beyond missions, and cheaper and more rapid access to space. This includes, besides low cost, shorter deadlines, reutilization of subsystems, greater volume demand, and more recent technologies practiced by all the main agencies.

According to AEB, the cost of doing business in the market for integrated circuits in Brazil is equivalent to about 10 million dollars per year including assets such as IP, human resources, licenses, silicon foundry runs, encapsulation, and intermediation in Brazil. Issues concerning funding (public at the beginning, but also venture capital, angel investors, corporate venturing), market niche, IP problems, and business model sustainability (service, IP licensing, fabless) are not yet clear.

It is necessary to identify design cycle and manufacturing steps for integrated circuits which are viable in Brazil, and also define demands to prioritize technological routes in: design (demands library); manufacturing; encapsulation; qualification and tests (internal capacities and external partnerships). From a strategic viewpoint, this is more desirable than thinking in terms of specific missions. A catalogue of critical technologies should be put together, in which all participants recognize their role in the development. IP issues should be discussed between participants at all levels,

to reach consensus on which are the critical technologies and the types of licenses involved in each phase, because of the public interest of the program. The main source of funding is public, and this shall trace the guidelines of the IP policy that should be followed. There is only one facility in Brazil, which may have process restrictions, low yield, and technology use limitations. Based on the collected data, having identified the different phases of satellite component production (figure 3), we attempted to link the participating organizations to each phase of satellite production aiming to support scientific missions in Brazil.

FIGURE 3
Phases of satellite components production



The direction should be the development of “radiation tolerant components for space applications”, which is the critical product demanded by the internal market. Considering the existent problem, from a commercial viewpoint, internal development (inside the network) should be prioritized, therefore efforts should concentrate on establishing, for the whole network, which role each actor should play in order for the products to be delivered. According to the theory, transactions which happen following a certain pattern and are supported in the network should be acknowledged by its members.

It became clear that AEB, the Brazilian Space Agency, should be responsible for coordinating the business group, because it has a central role in defining long term strategies involving technological aspects. The value produced by the network shall be recognized if it is able to deliver qualified components for satellites, and being competitive by complying with cost, deadline, technological and commercial restrictions (ITAR, for example).

The main technological issues involved in a space mission in the Brazilian program are satellite, subsystems, integration and tests, launch, ground segment, operation, management, and project documentation. The business group should

consolidate information and establish the actions each of other groups should take (i. Specification group; ii. Design group; iii. Fabrication and encapsulation group; iv. Radiation robustness tests group). In this sense, partnerships with outside foundries and ITAR may be of interest. An important question concerns IP and where it should focus, whether on the component, on the functional block or on its function (AEB, 2009).

Funding is a critical issue and should be linked to large programs, managed by public agencies, which include tax incentives; this will have implications for establishing viable business models for national industry.

6. Concluding remarks and theoretical and managerial implications

The case presented in this paper shows how a group of organizations, companies, and government institutions, belonging to Brazilian aerospace industry, are interacting and establishing relationships, and discussing their role, considering the global conditions of information and knowledge flows and regulations concerning the aerospace sector.

The approach adopted by the agents reveals the existence of an effort to work in a network perspective. However, this “network” has been encountering difficulties in defining individual roles to the participants.

According to the observed interactions, geographical proximity acts in a fundamental manner to foster deeper ties. The institutional setting also contributes to shape the network of relationships. There is a strong link between what is done in terms of research in universities and public institutions, where sometimes the university-industry link is represented by a person who is at the same time at the university, working as a professor or a PhD student, and a business partner.

In this network building process the intellectual property (IP) issues are a main concern. Each one of the institutions – universities, research institutions, and companies – has distinct objectives in this area. It is not clear to the research institutions and design houses what their IP goals are. By having a strict patenting policy, universities and research institutes may create obstacles for transferring critical knowledge to companies, thus slowing the innovation process that transforms technological knowledge into products applicable to satellites. In other words, in order to build value as a network, the appropriability regime, as some authors (AGRAWAL; HENDERSON, 2002; LAURSEN; SALTER, 2006; PERKMANN; WALSH, 2007) have expressed, must be moderately associated with strict IP rights.

The nature of knowledge produced in many of the institutions in the analyzed network is unhindered by commercial considerations, therefore suggesting that a free sharing policy may be adopted. It is crucial, therefore, according to Slowinski and Zerby (2008), that open discussions about IP risk happen between the different institutions, considering the linkage of agreements to market and technical intents of each party.

Considering the characterization and analysis of the structure, organization and functioning of the network of institutions in the Brazilian aerospace industry some managerial implications were identified and can be suggested: a) the agents of this industry could adopt long term programs as the main orientation. From a strategic point of view, this is more desirable than thinking in terms of specific missions. A catalogue of critical technologies should be put together, in which all participants recognize their role in the development; b) IP issues should be discussed between participants at all levels, to reach consensus on which are the critical technologies and the types of licenses involved in each phase, because of the public interest of the program. The main source of funding is public, and this shall trace the guidelines of the IP policy that should be followed.

The main issues involved in a space mission in the Brazilian program are satellite, subsystems, integration and tests, launch, ground segment, operation, management, and project documentation. The open innovation approach may be adopted to increase awareness and help clarify the different issues and bottleneck that the industry is facing. The business group should consolidate information and establish the actions each of other groups should take (specification group; design group; fabrication and encapsulation group; radiation robustness tests group). Considering the goals established by the network agents efforts should concentrate on establishing, for the whole network, which role each actor should play in order for the products to be delivered.

A secondary aspect of the present article, concerning the military nature of some organizations involved in the studied network, is that it may contribute with work culture necessary to develop critical technologies, which may require specific routines regarding confidentiality classification, strict deadlines, and organizational hierarchies. At the same time, as pointed out by Gallart (2008) and Stowsky (2004), the military innovation system is experiencing a process of change that alters fundamentally its relationship with its environment. This change refers to a transition from a mainly closed system of defense and security policy, to a more open system, in which technological and strategic factors are being transformed, external R&D

is assessed, with implications for the overall mode of knowledge generation and diffusion and technology integration. In the network presented in this article, such characteristics may have implications that are worth evaluating for future research in the field of open innovation.

In spite of revealing valuable insights on network dynamics, the present paper has limitations common to single case studies. Not all requested interviews were granted, mainly from companies, possibly limiting our understanding of certain problems related to the network and its development.

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