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Open innovation as an alternative for strategic development in the aerospace industry in Brazil

Abstract: *We present in this paper a case of technological competence development in the aerospace sector in Brazil, by addressing the complete cycle of integrated circuits for satellite applications, an area of high technology which is strategic to the country. The development of technological and business competences is linked to an understanding of the existing relations between different participating institutions, both public and private. There is an effort to establish a network for the development of radiation-hard integrated circuits in Brazil, comprising universities, research centers, private companies, design houses, funding and governmental agencies. These institutions have been working to define their roles, through participation in federally funded projects to develop robust component technology for the aerospace industry in Brazil. As a means to maintain and improve this network, it is suggested that long term planning tools such as technology roadmaps be adopted, as well as measures to increase awareness of and help clarify intellectual property issues, which is considered a significant bottleneck to advance technology development in this area. In this sense, open innovation may be considered an alternative for competitively enhancing the outcomes of the sector.*

Keywords: *Open innovation, Aerospace applications, Interorganizational network, Intellectual property, Technology roadmap.*

INTRODUCTION

This paper presents a case of technological competence development in the aerospace sector in Brazil, by addressing the complete cycle of integrated circuits for satellite applications, an area of high technology which is strategic to the country. The development of technological and business competences is closely linked to an understanding of the existing relations between different participating institutions, both public and private. To enhance the space program and to develop critical products, a focused development of resources is necessary. The open innovation management perspective is increasingly useful to analyze strategic technology development such as this one. The objective of this paper was to present to the aerospace community open innovation as an alternative for competitively enhancing the outcomes of the sector, focusing on the development of radiation-hardened systems and components for spatial application. It can also be an adequate approach to join actors of the Brazilian aerospace network around a common plan, developing the space industry as a whole in the country.

The main motivation to study this problem is that critical components may be subject to international commercial restrictions. There are some alternatives to overcome this, such as joint development with companies in other countries, upscreening of less qualified components, changes in engineering project, bilateral agreements for mission development, and the development of a set of radiation-hardened integrated circuits. Considering the effort of the Brazilian government in developing endogenous expertise in microelectronics, internal development of radiation-hardened integrated circuits is a viable alternative.

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Research context

The aerospace industry, in the context of the present study, 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 only in integrated circuits (semiconductors). However, this number does not reflect the entire deficit of the electronic industry, because imported electronic goods and the whole or parts of equipment with embedded semiconductors are not computed (Gutierrez and Mendes, 2009).

From a strategic perspective, the Brazilian aerospace program may act as a mechanism to foster networking among participating companies, establishing links between universities and research institutions to solve technological problems. The aerospace program may also provide scientific, engineering, and societal benefits, leading to accomplishments in space which may have inspirational value for young people, such as cited by Norman Augustine (IEEE Spectrum Aerospace, 2009).

In this context, our proposition is that the open innovation framework shall prove useful for analyzing the development of the network, in which many complementary competences, available in different institutions throughout the country, need to be coordinated, with the objective of building competences in the complete development cycle of integrated circuits for aerospace applications in Brazil. The cycle includes 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 concerning the institutional environment, business aspects, funding, intellectual property, technological trends, in which each institution or company contributes with a significant part of the development, and coordination of the group at the interorganizational level are discussed and alternatives for the network are proposed.

Method and data analysis

The method employed in this research was a case study of an interorganizational network. This network 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 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, 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 during a three-day workshop held in October 2009 in *São* José dos Campos, São Paulo, Brazil, to discuss the effects of ionizing radiation on electronic components, in which companies, universities, research and government institutions participated. Data collection consisted of direct observation of the presentations and also interviews with a key representative from each of the following organizations: the Brazilian Space Agency (AEB), the Association of Aerospace Industries of Brazil (AIAB), two federal research institutions, brazilian design houses, two universities, the Ministry of Science and Technology, and Brazil's development bank (PEICE II, 2009). Questions were related to business aspects, funding, intellectual property, technological trends, and coordination of the group at the interorganizational level. Additional data were collected immediately after the workshop 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.

Open innovation and interorganizational relationships

Innovation studies have emphasized the growing relevance of external sources of innovation. Rather than relying exclusively on internal research and development (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, Loput and Smith-Doerr, 1996; Coombs, Harvey and Tether, 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).

By definition, open innovation occurs through the establishment of links between innovative firms with other institutions. In open innovation a firm collaborates with technology providers, suppliers and/or customers (Von Hippel, 1988) to improve its internal innovation capabilities or to expand the markets for the external use of internal innovations (Fig. 1) (Chesbrough, 2003). In an open innovation context, firms jointly create value through a number of transactions in so-called value networks.

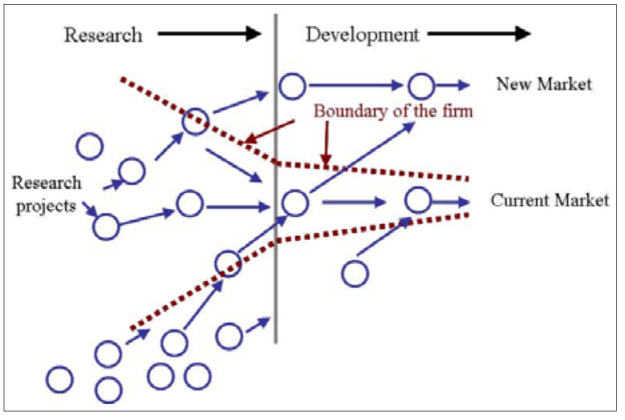


Figure 1: Open innovation model (Chesbrough, 2003)

Networking is a crucial dimension of open innovation, and the role of interorganizational relationships in a context of open innovation has been studied in recent years (Vanhaverbeke, 2006; Vanhaverbeke and Cloodt, 2006). Analyzing this context, the authors affirm that 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. According to Von Hippel (1988), the high costs and uncertainty in knowledge creation are powerful reasons to explain why firms frequently resort to external sources of ideas. Research on innovation has emphasized the role of the firm's external dimension as an important locus of useful knowledge (Arora and Gambardella, 1994; Caloghirou, Kastelli and Tsakanikas, 2004; Cassiman and Veugelers, 2006; Lichtenthaler, 2008a). 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 and Duysters, 2007).

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 partners' objectives are aligned and on their commitment to invest in complementary assets (Vanhaverbeke, 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 to the increasingly global nature of markets and economies, which results in a global division of labor and in a more intense competition (Álvarez, Marin and Fonfría, 2009). According to these authors, motivations for cooperation are grouped into two items: i) the complex and uncertain (and thus costly) nature of research and technological development, and ii) market access and search for opportunity.

In the dynamic capabilities approach, Teece, Pisano and Shuen (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 and industry, which remains under-researched (Perkmann and Walsh, 2007). From the perspective of a firm, the types of networks that influence its search for university partners are geographically proximate social networks (Jaffe, 1989; Owen-Smith and Powell, 2004). The issue of geographic location of innovation and its implication for open innovation has been recently developed by Simard and West (2006).

Intellectual property

An intellectual property (IP) policy for a network is a challenging arrangement. Multiple parties have different interests that must come into balance. Defining IP rights enables the exchange of ideas and technologies between the many parties who possess useful knowledge (Chesbrough, Vanhaverbeke and West, 2006).

In the open innovation paradigm, changes in the general role of IP have been observed, particularly in patenting practices. This may be attributed to technological changes, in which IP rights 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 the emphasis of a patent as the sole mechanism of competitive advantage.

Based on a survey, Cohen, Nelson and Walsh (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 cooperative 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 and Walsh, 2007).

Laursen and Salter (2006) 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. In this direction, other authors (Chesbrough, Vanhaverbeke and West, 2006; Fabrizio, 2006) identify potentially negative impacts of high appropriability upon the cumulative and decentralized aspects of open innovation, 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.

Roadmaps

When considering investment in technological innovation, it is suggested that policy makers grasp the broader coverage of scientific and technological research, and make decisions on effective investment in especially promising and emerging technologies, under circumstances where total budget has been constrained or has declined. In this sense, policy makers and R&D managers have to notice global trends in research and emerging technologies, which enables precise forecasting and effective roadmapping. Nowadays, in the increasingly knowledge-based economy, a more reliable growth depends on the application of new science and technology (Kajikawa *et al.*, 2008).

Technology roadmaps are a flexible approach, in terms of the different organizational aims they can address. They should integrate commercial and technical knowledge, and their purpose is to give a clear picture of where an organization (or a group of organizations) is headed, in terms of its technology, the local environment of which it is a part, and who are the participants in its market. Roadmap models consider the need to consolidate multiple views of technology development. According to Lichtenthaler (2008b), it is an instrument that may help firms to incorporate external knowledge exploitation in strategic technology planning. Some types focus on integration of technology, in terms of how different technologies combine within products and systems, or to form new technologies. Other models are used for long-range planning. This type of roadmap is often performed at the sector or national level (foresight), and can act as a radar for the organization to identify potentially disruptive technologies and markets, aiming to converge to a specific enterprise, as shown in Fig. 2 (Phaal, Farrukh and Probert, 2004).

According to Phaal, Farrukh and Probert (2004), a key challenge to overcome if the roadmap is to be widely adopted is keeping it alive; its full value can be gained only if the information that it contains is current and kept up-to-date as events unfold. In practice, this means updating the roadmap on a periodic basis, at least once a year, or perhaps linking it to budget or strategy cycles.

A few roadmaps have been developed in Brazil, although its use as a strategic planning tool is still quite limited. Some examples include the nanotechnology roadmap for space industry (Fellows and Vaz, 2006)) and the ethanol technology roadmap (Graziano, 2009). Both were conducted by governmental organizations.

Overview of the Brazilian aerospace sector

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, a cooperation agreement 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 the National Institute for Space Research (INPE), which is responsible for the projects: *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 aerospace sector has two satellite launching programs under development, which intend to offer in the future launching services to the market. The first program is a joint effort of Defense and of Science and Technology Ministries, the VLS program. The second one is related to a bi-national company, the Cyclone 4 program.

In the satellite segment, the country does not have yet a communication satellite development program. There are, however, competences in equipment and subsystems.

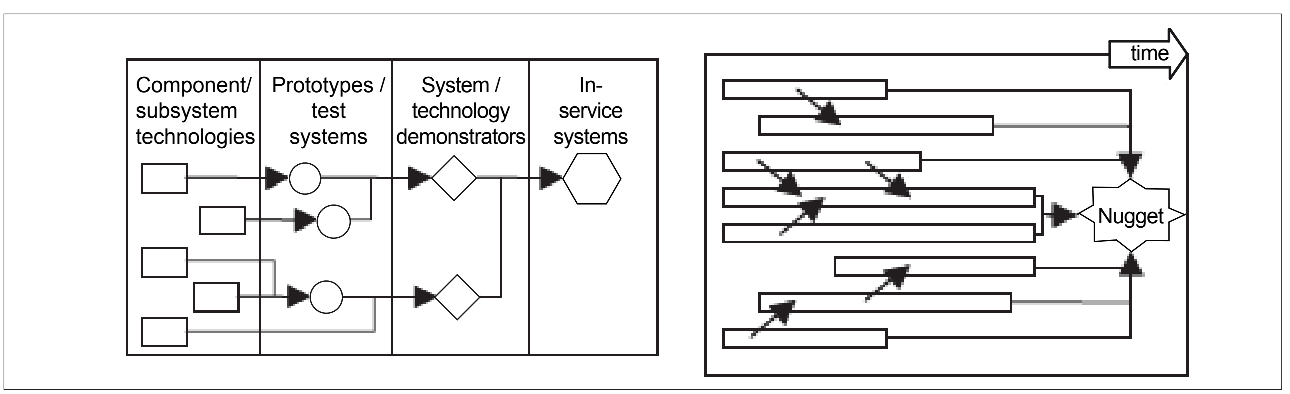


Figure 2: Roadmap models (Phaal, Farrukh, Probert, 2004, p. 12)

In the services segment, there are more than 30 communication satellites supplying the Brazilian market. Brazilian companies operate around 10 satellites.

Research institutions

The Department of Aerospace Science and Technology (DCTA) was created in the 1950s in São José dos Campos to build capabilities in the aeronautical area. Nowadays, its objectives encompass the aerospace area. It comprises several research institutes for aerospace and defense, including: the Technological Institute of Aeronautics (ITA), which has graduate and undergraduate courses, research and extension activities in areas of interest to the Brazilian Air Force and to the aerospace sector in general; Institute of Aeronautics and Space (IAE) and Institute for Advanced Studies (IEAv), where pure and applied science and also technological development in various fields of aerospace area are conducted (DCTA, 2009). DCTA is also in charge of the Brazilian launching centers.

INPE, linked to the Ministry of Science and Technology, also located in São José dos Campos, is the main research institute for space, astronomy, meteorology, and related areas in Brazil. It was created in 1971, from the Group for the Organization of National Space Activities Commission, the embryo of the institute, which had been created in 1961. R&D are conducted in areas such as space and atmospheric sciences; weather forecast and climate studies; space engineering and technology; Earth observation; satellite tracking and control; integration and testing laboratory. INPE is the executive organization responsible for coordination and implementation of R&D activities in 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, reception, processing and distribution of satellite data. Nowadays, INPE is the main client for spatial subsystems. Industry defines the project and the necessary components, which are purchased by INPE in the international market, with spatial specification when possible. Thus, it is today the main client in Brazil for radiation resistant components applied to the national satellite program, which supplies a satisfactory indicator of the R&D needs for such components, and their qualification for space environment (INPE, 2009). Recently, this orientation seems to be changing and the industries will also be in charge of purchasing parts and components. An example is the Multi Mission Platform (MMP) project, which is expected to follow this new orientation.

Space agency

AEB was created in 1994, and is responsible for the formulation and coordination of the 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 the modernization and leveraging Brazil's entire productive sector, through technology absorption mechanisms.

The agency also manages international cooperation, which is important for building technological capacity in the space sector. Agreements 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).

Companies

Companies participating in the network vary in size and age, ranging from 30 to about 450 employees. The first companies were established in the 1980s; others were established during the 1990s to work in the electronics, avionic and space industries, working with both civil and military clients. Most of the companies 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, because these ties benefit from highly qualified professionals who seek jobs in the region. They have in common research-based origins, since all were created by former researchers. All of them 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 the National Aeronautics and Space Administration (NASA), European Space Agency (ESA), French Government Space Agency (CNES), and Indian Space Research Organization (ISRO). One of the companies has participation of EADS Astrium as a shareholder, the largest European company in the aerospace and defense sectors. According to one interviewed CEO, companies in the Brazilian space sector seek ideas for products and applications in foreign space programs, developed also by foreign companies.

AIAB is the national entity which represents companies in the Brazilian aerospace sector. 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. The position of AIAB is that it should strive to reach significant participation in the space market, analogously to the Brazilian aviation industry. 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).

Universities

Brazilian universities, both public and private, state and federal, 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.

The ITASAT project, a federally funded project, involves academic participation from Brazilian public universities. It started in 2005, and its goal is to develop a university-built satellite, giving students the opportunity to conduct technological experiments with space applications. The idea is to transfer manufacturing of flight and qualification models to national industry. Initiatives such as ITASAT are extremely relevant to develop space related activities in Brazil, because they contribute to educate highly qualified human resources, bringing the space program closer to universities, and creating means to develop knowledge in science and technology (ITASAT, 2010).

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 to Brazilian technological institutions or to multinational companies in the sector. Brazilian industry would be the potential client for design houses services (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 the Center for Information Technology Renato Archer (CTI), especially for building competences in designing radiation-hard components, following strict international standards (Finco, 2009). CTI, which is a R&D unit for information technology of the Ministry of Science and Technology, founded in 1982 in Campinas, São Paulo, has a design house (CTI-DH) with 40 employees, offering consulting services in electronic components and systems design, manufacturing, as well as qualified IP production for the global market, with application in wireless products, sensor networks, automotive, consumer electronics, among others. CTI interacts intensely with academic and industrial sectors through research cooperation agreements, with ten laboratories dedicated to electronic components, microelectronics, systems, software, and IT applications, and with almost 300 employees.

Another publicly funded design house in Brazil is CEITEC, located in Porto Alegre (southern Brazil), with almost 100 collaborators. A production facility is also located there. Throughout Brazil, there are over 10 other design houses.

Technological restrictions in component development

The main differences between conventional component technologies and radiation resistant technologies reside in the design step, and are related to quality, resistance to cosmic radiation, temperature operation range, and resistance to mechanical vibration and operation in high vacuum environment. Conventional integrated circuit design techniques must be upgraded to satisfy requirements for aerospace applications, or specific manufacturing steps should be adopted. There is sufficient consensus that IC design has influence on characteristics related to radiation resistance and quality standards, so 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). Critical components may be subject to international commercial restrictions (ITAR – International Traffic in Arms Regulations), and must be internally developed (AIAB, 2009).

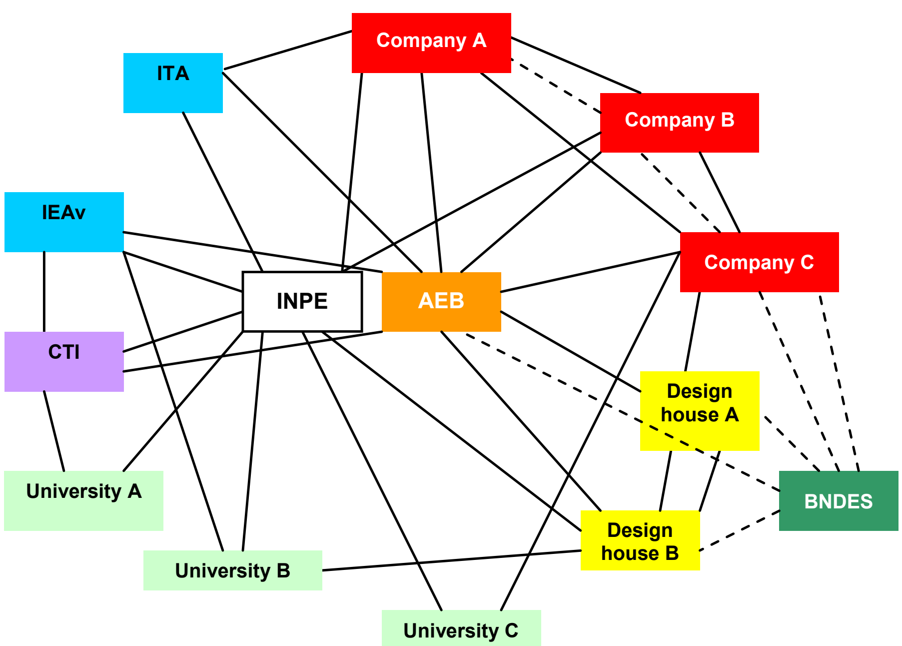
The network

Figure 3 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. The Brazilian Bank for Social and Economic Development (BNDES), founded in 1952, is the country's largest investment bank, acting as a major supporter of the industrial policy of the government. Among its objectives there are fostering technological innovation and competitiveness of the electronics industry in Brazil, thus establishing links mainly to companies and design houses, and with AEB for creating funding guidelines for the sector (expressed by the dotted lines). Other national funding agencies for science and innovation, such as CNPq, FINEP, and FAPs, which may fund partnerships between public and private institutions, were not included in Fig. 3, but are nonetheless important actors in the technological innovation process.

This group of institutions took part of the II Workshop on Radiation Effects on Electronic and Photonic Components for Aerospace Applications, as mentioned above. The proposed objectives of this workshop were: a) to disseminate knowledge on the effect of ionizing radiation on components and materials of aerospace interest; b) to promote integration between policies 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; c) to identify short term demands (two to four years) for R&D on ionizing radiation effects on electronic and photonic devices, aiming satellite applications; and d) to 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 developing 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.

Thus, participants were able to have direct contact with the concerns of the sector, objectives and necessities related to the aerospace sector. Moreover, they were



CTI: Center for Information Technology Renato Archer; IEAv: Institute for Advanced Studies; ITA: Technological Institute of Aeronautics; INPE: National Institute for Space Research; AEB: Brazilian Space Agency; BNDES: Brazilian Bank for Social and Economic Development.

Figure 3: Network of institutions in the aerospace industry in Brazil.

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; the identification and consolidation of common necessities and ways of seeking support in official funding bodies; the discussion of strategic guideline propositions for the sector, and the evaluation of 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 following the workshop. One of the objectives of the group (business group) was 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 robust components; justification for the proposed developments and possible impacts in other areas of interest to the country. To survey problems and strategic solution proposals related to IP is also a concern for the group.

Business issues in the Brazilian space program

To further advance in the proposed developments, according to AEB, PNAE must be reviewed on topics such as putting more emphasis on a program orientation and building a catalogue of critical technologies. Radiation hardening should be considered in the development cycle of integrated circuits. Ten percent 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. A typical project in Brazil has a two-year schedule, at the cost of a few million dollars. Considering necessary investments, 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 the use of more recent technologies than those practiced by all the main agencies (AEB, 2009).

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. Funding is a critical issue and should be linked to large programs, managed by public agencies, which include tax incentives for those who invest in innovative projects. At the beginning, it may be public, but later may also include venture capital and angel investors. This will have implications for establishing viable business models for national industry. Related issues such as market niche, IP problems, and business model sustainability (service, IP licensing, fabless) are not clear yet.

It is necessary to identify design cycle and manufacturing steps for integrated circuits which are viable in Brazil, and also to define demands to prioritize technological routes in: design (library demands); manufacturing; encapsulation; qualification and tests (internal capacities and external partnerships). There is only one manufacturing facility in Brazil, which may have process restrictions, low yield, and technology use limitations. In this sense, besides investments in manufacturing facilities in Brazil, partnerships with outside foundries 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).

RECOMMENDATIONS AND CONCLUDING REMARKS

Steps that are considered viable in Brazil should be part of the orientation on long term programs. Strategically, this is more desirable than thinking in terms of specific missions. A catalogue of critical technologies may be put together, in which all participants recognize their role in the development. Issues concerning intellectual property should be discussed between participants at all levels, in order to reach a 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 issues presented above, that have been preliminarily discussed by the group during the workshop, lead to suggestions aiming to develop the sector and to bring plausible solutions to the presented problems. It is suggested that a roadmap be developed, adopting a model for integration planning as shown by Phaal, Farrukh and Probert (2004). According to PNAE, an explicit time frame (2005-2014) should be considered for the program.

Based on the collected data, roadmap models may be adapted to suit the workgroups that were formed at the workshop, linking participating organizations to each "phase" aiming to support scientific missions, in this case, satellite building in Brazil (Fig. 4). 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 that the other groups should take (i. Specification group; ii. Design group; iii. Fabrication and encapsulation group; iv. Radiation robustness tests group).

The direction − "nugget", as proposed by Phaal, Farrukh and Probert (2004) − should be the development of "radiation tolerant components for space applications", which is the critical product demanded by the internal market, impacting the sector as a whole. Considering the existent problem, from a commercial point of view, internal development (inside the network) should be prioritized, therefore efforts should concentrate on establishing, for the whole network, the role that each actor should play in order to deliver the products.

In a configuration of open innovation, IP issues are a main concern. Each institution – universities, research institutions, and companies – has distinct objectives concerning IP issues.

A well defined patenting policy, considering all actors' interests, is of main concern in order to guarantee that critical knowledge and technologies be transferred to companies, and to avoid delays in the innovation process that transforms technological knowledge into products applicable to satellites.

This step generally takes place in companies, in close collaboration with INPE, in which the first have to build or acquire capacities to be able to answer demands of the space program, all with cost implications and deadlines. In other words, in order to build value as a network, the appropriability regime, as some authors (Agrawal, Henderson, 2002; Laursen, Salter, 2006) 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.

According to the observed interactions, geographical proximity of most of the institutions participating in the aerospace program facilitates knowledge exchange, both formally and informally. 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, and 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 as a business partner. This same individual maintains contact with a research group, interacting and searching for new ideas to implement in his/her start-up company. These roles must be sorted out in order to organize a sustainable strategy for the space industry. The client for qualified components (INPE, in this case) must know which competences can be made available inside the country. In this way, this client may specialize in defining mission prerequisites and contracting local companies to conceive, develop, and implement the

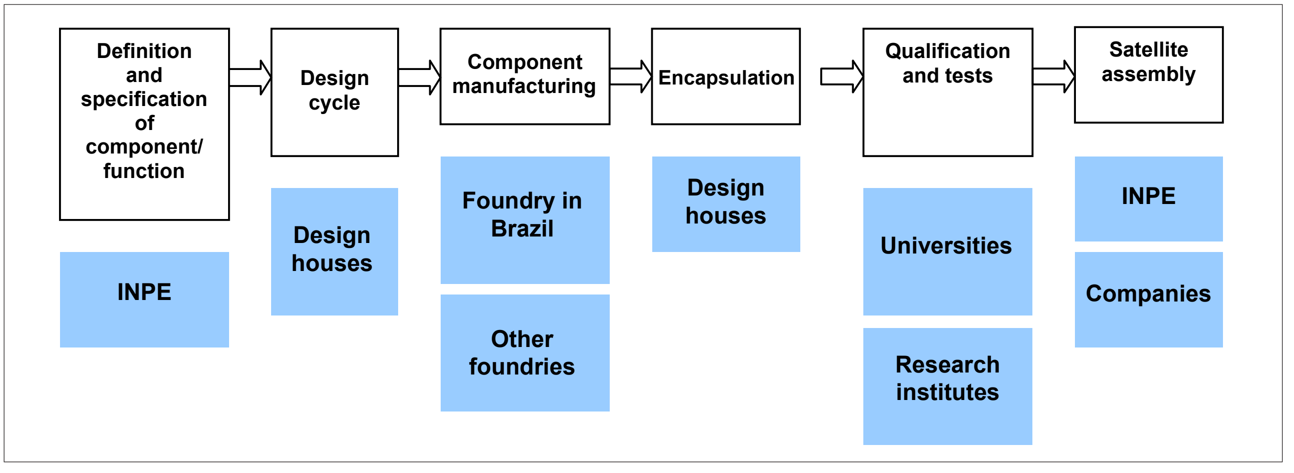


Figure 4: The proposed roadmap.

program, establishing development and manufacturing schedules considering all possible partners.

The case presented in this paper shows how a large group of research organizations, companies, and government institutions in the aerospace sector in Brazil is trying to discuss its role. A main concern for these actors is building critical professional competences. This includes fostering higher education in order to maintain qualified human resources where they are needed to develop critical technology, mainly in companies, instead of depending exclusively on graduate and undergraduate students with a research profile. This issue poses a difficulty, inasmuch as there is a high staff turnover, causing project discontinuities.

It may be concluded that there is a network; recently, the institutions have been working to define their roles, through participation in federally funded projects to develop robust component technology for the aerospace industry in Brazil. A suggestion to maintain and improve the network would be to adopt long term planning tools, such as technology roadmaps, integrating all members of the network. The open innovation approach may be adopted to increase awareness of and help to clarify IP issues. As the analysis revealed, this may be a significant bottleneck to overcome in order to advance technology. The network shall be recognized if it is able to deliver qualified components for satellites, being competitive by complying with cost, deadline, technological, and commercial restrictions (e.g. ITAR).

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, which possibly limited our understanding of certain problems related to the network and its development. We suggest further study in this area.

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