Journal of Technology Management & Innovation

Received August 14, 2006/ Accepted August 24, 2006

THE DYNAMIC COOPERATION NETWORK AS AN INSTRUMENT FOR THE TECHNOLOGICAL MANAGEMENT AND INNOVATIONS PROCESS: THE CASE OF THE BRAZILIAN AERONAUTIC SECTOR.

João Amato Neto, Mauro Catharino Vieira Da Luz, Cristiane Chaves Gattaz.

University of São Paulo, Brazil
amato@usp.br

Abstract

The articulation of the Science, Technology &Innovation actors and the development of collaborative actions are essential to improve the efficiency and the effectiveness of the Brazilian aeronautic process and to maintain its global competitiveness. The present paper analyzes the dynamic cooperation network model of the Brazilian aeronautic sector based on the case study executed in joint with the Industrial Promotion and Coordination Institute (IFI) – an organization responsible for the industrial support and infrastructure programs to improve the quality and the training of this sector. As a result, this work identifies some critical factors for success related to the cooperation network model for the growth of the sector competitiveness potential.

Key-words: Cooperation network; technological management; Collaborative actions.

1. Introduction

The Brazilian aerospace industry consists of collecting complex processes and products which are intensive in engineering and technology and where the necessary production competencies are generated by meeting several companies and scientific and technological institutions. In this context, the aerospace industry is composed by a Science, Technology & Innovation (S,T&I) system in which is articulated and coordinated in a network structure through projects that meet civil (aeronautic industry) and military (aerospace industry) needs.

In the 80s, the feasibility of aerospace projects started to highly depend on consortia and alliances (cooperation models) to meet the required competencies and mitigate project risks (BONNACORSI & GIURI, 2001). In such context, the internationalization and organization of the global aerospace production chain happened in joint with the consolidation process from which originated the big groups of the sector (ESPOSITO, 2004).

So the aeronautic production is currently organized as a global network, consisted of big integrators, represented by Boeing and the Airbus consortium; of the components and subsystems industry; and, of specialized integrators such as Embraer. These agents compose a hierarchal system of production that puts competition into effect from the accomplishment of projects and the necessary cooperation for its development because of the complexity for production, projects risks, and the necessary volume of resources.

In Brazil, the aerospace S,T&I system is concentrated in the region of São José dos Campos of São Paulo state, where the Aerospace Technology Center (ATC) – institution responsible for the technological competencies of the basic system – and Embraer, the leading company of the regional aircrafts segment and fourth biggest industry assembler, are located. Since the end of the 90s, the aeronautic arrangement, organized to meet the demand of Embraer and the military needs, has been reorganized to be adequate to the demand of integrated systems and to focus on space technology of military projects.

The organizational adequacy for qualification based on competitive requirements of the international aerospace subsystems industry context, and the technical and operational training stand out among challenges faced by the Brazilian aerospace S,T&I system (BERNARDES, 2000). So the aerospace system will have to redefine the model of interaction and articulation to guaranty the necessary conditions for production competitiveness.

So this present work approaches the general characteristics of network models currently being used by the Brazilian aerospace S,T&I system and its implications for the competitiveness of the chain. In this way, the starting point of this work is the study of the coordination area of the Industrial Promotion Institute of the Aerospace Technology Center (IPI/ATC) – an institution responsible for interfacing technology transfer agents through its services: off-set agreements, tax incentives negotiation and qualification of industrial companies.

This work is also organized into the following 5 sections. The 2nd section presents the relationship between cooperation networks and competitiveness based on literature. Both 3rd and 4th sections present, in this order, the researched case and the applied research methodology. The next section, points out the main research results. Finally, the last section presents the conclusion and suggests other research challenges for future studies.

2. Innovation and technological paradigms

Accompanying the evolution of the scientific paradigms, the technology and the productive organization also underwent several radical transformations, as illustrated by SCHUMPETER so well (1984), analyzing the fundamental role of the innovative force inside the creative destruction process. More recently, other authors also offered new interpretations concerning the technological paradigm. NELSON & WINTER (1977, 1982) used the concept of technological regime to define borders of the technical progress, as well as to indicate guidelines to reach such borders. On the other hand, DOSI (1982) states that, after the establishment of a certain paradigm, a normal development process would follow along a technological trajectory, defined by the own paradigm. Afterwards, new paradigms would appear from the opportunities created by the scientific progress as well as in function of the growing difficulty in moving forward along the existent paradigm. New productive sections would be intimately associated to this new technological paradigm. Since the beginning of 70´s a group of revolutionary innovations have stimulated radical changes in the whole productive structure of the world industry: laser, optic fibers, genetic engineering, microelectronics and infoways forebode the coming of a new technological and industrial paradigm.

2.1. The microelectronic paradigm and the lean and flexible production systems

From an eminently technician point of view, it is possible to understand that the new microelectronic paradigm means that the "search for the solution of problems of reception, treatment, transmission and reception of the information based on the solid state physics, using the integrated circuits as main material component" (ERBER, 1986). Constituting a revolutionary innovation, this new technical base creates new perspectives for the modern society and especially for the new digital economy. FREEMAN (1982) emphasizes this revolutionary aspect of microelectronics due to the fact that this technology empowers the introduction of new products and services, besides the fact that there is an enormous possibility of pervasiveness of this new technology in several economic sections, implying in significant changes in the cost structures of the input, changing the production and distribution conditions of goods and services.

Analyzing the main characteristics of this new technician-economic paradigm, based on microelectronics, PEREZ (1985) points out a series of advantages of this paradigm, especially those concerning the information-intensive production systems, whose companies usually act in the most modern and dynamic sections of the economy. The advantages are: a.) The minimization of energy and material consumption in the several production processes; b) The obtaining of high levels of precision and, consequently, the possibility to produce with narrow tolerance margins; c.) Higher inventories controls; c.) Higher quality control in the production processes, which consequently allows a significant reduction of wastes, scrap and refuses; d.) Finally, and a direct consequence of the other items, the new paradigm enables a considerable elevation of the productivity of the resources.

The development and diffusion of microelectronics technology and computer science, specially through the computer and other intelligent components, constituted the vital elements of the integration of the project area with several functions of the production system. Besides, the microelectronics paradigm makes possible the largest productive integration inter-units of a same company and among companies (customers and vendors), by computer nets operating online.

In this context, the change of technological paradigm propitiated by the development of microelectronics enabled a new manufacturing strategy through the substitution of conventional, specialized and dedicated machines for programmable multi-functional machines. Under this new paradigm, the production system of goods and services developed a new standard: instead of the traditional production, with great volumes and limited variety of standardized products, a new reality can now be found, with the production of a wide variety of small lots of differentiated products.

Technological Strategy and Change and Competitiveness

According to PORTER (1992), technological strategy is the method of the enterprise to develop and use technology. Although it comprises the most obvious role of R&D departments, it is much more comprehensive, due to its penetrating impact over the value chain. He also states that technological strategy should help to answer three basic issues:

- The new technologies to be developed;
- Whether technological leadership should be sought in those technologies;
- The role of technologies' licensing

The technological strategy should be reinforced by functions and activities constantly. Porter (1992) states that since technological change has the power to influence industrial structure and competitive advantages, it should be one of the main components in an enterprise's global strategy. Such statement can be exemplified: a technological strategy designed to achieve product performance differentiation will lose much of its impact if, for instance, a highly trained sales force isn't available to explain the performance advantages to a buyer, or if the manufacturing process doesn't have the necessary capabilities to secure the required quality control.

In the heart of a technological strategy is the level of competitiveness the enterprise is trying to achieve. Technologies to be developed are those who best support the enterprise's overall strategy, relatively to its development success probability. Thus, the technological strategy consists a potentially powerful tool to allow the enterprise to comply with its overall strategy, as long as technological efforts are in accordance with it (PORTER, 1992).

Technological change can occur in various types, according to its level of originality, complexity and scientific intensity. Considering those aspects, technological change can be analyzed according to its generators and users. According to FURTADO ET AL (2003), technological change in an enterprise, be it product or process related, can be:

- Duplicative imitation: incorporation of technologies generated by other agents than the enterprise, without any contribution in terms of altering the characteristics of the technology. Technological effort required in this case is of mere absorption and usage of the technology.
- Creative imitation: also refers to the incorporation of others' technologies, but with original contribution from the enterprise to adapt or improve the technology. In this sense, there exists a real effort in terms of adapting this technology to the enterprises' particular needs or goals;
- Original innovation: refers only to the exclusive generation and introduction for the first time in the market of a product or process technology by the enterprise. Thus, innovation refers only to the original technological knowledge generation.

The decision to adopt the concept of technological change derives from the frequent difficulty found in technology studies or papers, that usually do not discern between innovation through adoption (duplicative imitation and, sometimes, creative imitation), and innovation through efforts (creative imitation and original innovation). Sometimes, both enterprises that contributed with a creative element to the change, and those who simply introduced a change that was developed by another enterprise, were considered innovative ones.

Strategically, any technological change can be conducted to achieve specific objectives, with the ultimate goal to raise the competitive positioning of the enterprise. Also, the directions of the technological strategy and technological changes are much guided by the stage of the product's life cycle, by the conception of the dominant project, and by the technological trajectory of the enterprise, considering its restrictions (UTTERBACK, 1994).

3. Cooperation network nature

Complex cooperation network models in general have been structured upon a considerable number of inter-related nodes and connections. Each node can be represented by an individual, an institution, a company or a community which has a specific role toward the objective the network is being developed. Also, these nodes connect to each other through certain interaction and communication protocols to build necessary relationships to execute a specific production process. The inter-relation between these nodes and connections are based on several contexts, either internal or external business environment, which are part of the objective strategy in action.

In this sense, the following sub-sections will take into consideration, upon literature research, the main variables from which a cooperation network model is developed in order to accomplish the objective of this work: network actors, interaction and communication protocols and environmental characteristics. Essentially, these sub-sections will present a link between the cooperation network typology (complex networks and its different forms of relationship), some current interaction and communication protocols (telecommunication technology and in presence form) often used, based upon the existing environment of the Brazilian aeronautic sector (network context).

3.1. Cooperation networks

In recent years, theoretical researches in the "complex networks" field (COSTA, 2005) have proposed many different models and properties of these networks that enable the simulation of natural phenomena and men-made structures to investigate inter-firm relationships, such as alliances, partnerships, consortia, networks, clusters, joint-ventures etc. (AMATO NETO, 2005). Each model analyses and explains different and complementary aspects, focusing on the nature and characteristics of inter-firm complex relationships.

Besides some of these aspects were originated from the complexity theory, social interactions have become the next phase of the "complex networks" history. Many inter-firm relationships such as clusters have been structured by relatively weak connections. In other words, these relationships have been more informal and personal other than formal. Nowadays, the Internet, Intranet and Extranet have been one of the main objects of study in this field. The restructuring of the industrial organization structure in the new digital economy is heavily influenced by the change of strategies of the transnational institutions around the world, and it is also dependent on the capacity of firms in terms of creating competitive strengths in the new forms of collective organization networks and chains which are characteristic of the new era. As a consequence, industries are deeply changing their traditional structures and reorienting their strategies. In this context, industrial communication protocols within the industrial organization structure are in change. This is already a reality into the Brazilian aeronautic sector. Embraer intensively links its vendors, customers, employees and technological partners through the most varied forms of electronic nets (Internet, Intranet, Extranet and Local Networks). In this sense, the organizational structure of Embraer implies drastic changes into the industrial strategies.

3.2. Virtual networks

The concept of virtual organization or virtual enterprise is especially pointed out as a strategic network among global companies that can create a lot of new opportunities for the partners belonging to a specific digital network. Moreover, the term Virtual Enterprise (VE) has become prevailing in multidisciplinary research and development initiatives (KATZY, 1998b). Operations related to production, marketing, logistics, product development, R&D, material supply, engineering, and so on can be highly improved through the intensive use of IT and new telecommunication channels.

Virtual organization is a special kind of enterprise cooperation network that creates dynamic cooperation networks by the intense use of new information and telecommunication technologies (Internet, for instance) and has the following goals:

- To render access to new possible markets, without the traditional space and time constraints;
- To improve competitiveness potential of partners of this virtual network;
- To make the innovation and exploitation of new business opportunities in the global market possible.

Based on Bremer (1996b) *apud* Goldman, Nagel & Preiss (1995), the adoption of the virtual organization structure under the competitiveness analysis can point out the following strategic reasons:

- To share resources, facilities and core competencies in order to expand the geographical range or the apparent potential that a rival company or industry can offer a client;
- To share the risk and the infrastructure costs to be a competitor.

According to Zimmermann (1997), the term "virtual" is used in a broad sense to explain something that apparently exists, such as virtual reality or virtual product/virtual object; so these do not have any physical structure. They only exist in the computers. To the observer, they only exist in the mind, as a product of imagination.

A virtual enterprise can be understood through two points of view: institutional and functional. Concerning the first point of view, a virtual enterprise is an arrangement of the best core competencies of independent companies which cooperate with each other. They are connected through the use of the new information and telecommunication technologies during a certain period of time. This period corresponds to the achievement of a specific business purpose without considering the companies' boundaries of their original industries and countries. It is necessary to emphasize that a lot of difficulties in terms of governmental regulation have arisen.

In this enterprise network configuration, each member has access to the existing resources in the whole network. The risk of each member is shared among the partners of this network, especially in large projects.

Nevertheless, concerning the final client, the aim is to get low cost and better quality products. Besides, they can have many more possibilities of getting better services, although this final client can see only one supplier.

Concerning the functional point of view, one main characteristic of a virtual enterprise is the concentration on core competencies, which are coordinated in a dynamic way and guided to problem solving, through a superior base of IT. According to this approach, a virtual enterprise is not seen as an additional organizational form only. It is a

ISSN: 0718-2724. (http://www.jotmi.org)

quality that can be applied to an existing organization.

3.3. Consortium

Traditional organizational structures have been changing to a less hierarchal relationship base. Therefore, the development of new relationship patterns between suppliers network, involving big, medium and small companies, becomes necessary.

Current tendencies of reorganizing the supply patterns are going through new concepts and organizational arrangements such as the "modular consortium" or "industrial condominium" (AMATO NETO & MARINHO, 2001). Some traditional functions/activities of parts and components assembly are being transferred from big clients (assemblers) to their suppliers, which start acting, inclusively, within the clients own plant.

All forms of cooperation networks can be virtual or not. Consortia are usually practiced using informal protocols and pursue, besides, an additional strategic reason for cooperation: supply chain management.

Both forms of cooperation network described above will be discussed in the present case study.

4. The Brazilian aeronautic cooperative arrangement for innovation and production

In the 50s, the Aerospace Technology Center (ATC) was created and established in the city of São José dos Campos , state of São Paulo, as an executive institution of the Technology Research & Development Policy for the defense area of the Aeronautic Ministry. This institution organizes its activities through the Aeronautic Technology Institute (ATI); Space and Aeronautic Institute (SAI); Advanced Studies Institute (ASI); and, the Industrial Coordination and Promotion Institute (ICPI).

ATI, SAI and ASI activities are related to R&D. The ATI is mainly responsible for educating the sector's technical work force in the aeronautic engineering field. The SAI concentrates its activities in aerospace technology R&D (materials, tests, belic systems). The ASI turns its activities to pure and applied science (physics, laser and digital electronics). The technology transfer, training, quality and basic industrial technology services for the chain is offered by the ICPI.

The ATC in joint with those institutes compose the basic structure of the S,T&I system, from what the Brazilian aerospace production chain was organized. Within this structure, the Aerospace Promotion Coordination (APC) – an institute that establishes the interface between the S,T&I system and companies (organized in form of consortium) of the aerospace industry to meet the interests of the Aeronautic Ministry – plays an outstanding role, being responsible for the technological and industrial compensation service, industrial coordination and promotion and catalogue and articulate industrial companies.

The technological and industrial compensation service deals with the attendance of the technology transfer processes associated with international contracts, which are known as "offset". The Industrial Promotion service is attributed to execute the evaluation and registration of the Aerospace chain for tax incentives concession. Also, it supports the protection of intellectual property rights. The Industrial articulation service devote to the adequacy of the industrial capacity to meet the Aeronautic Command needs.

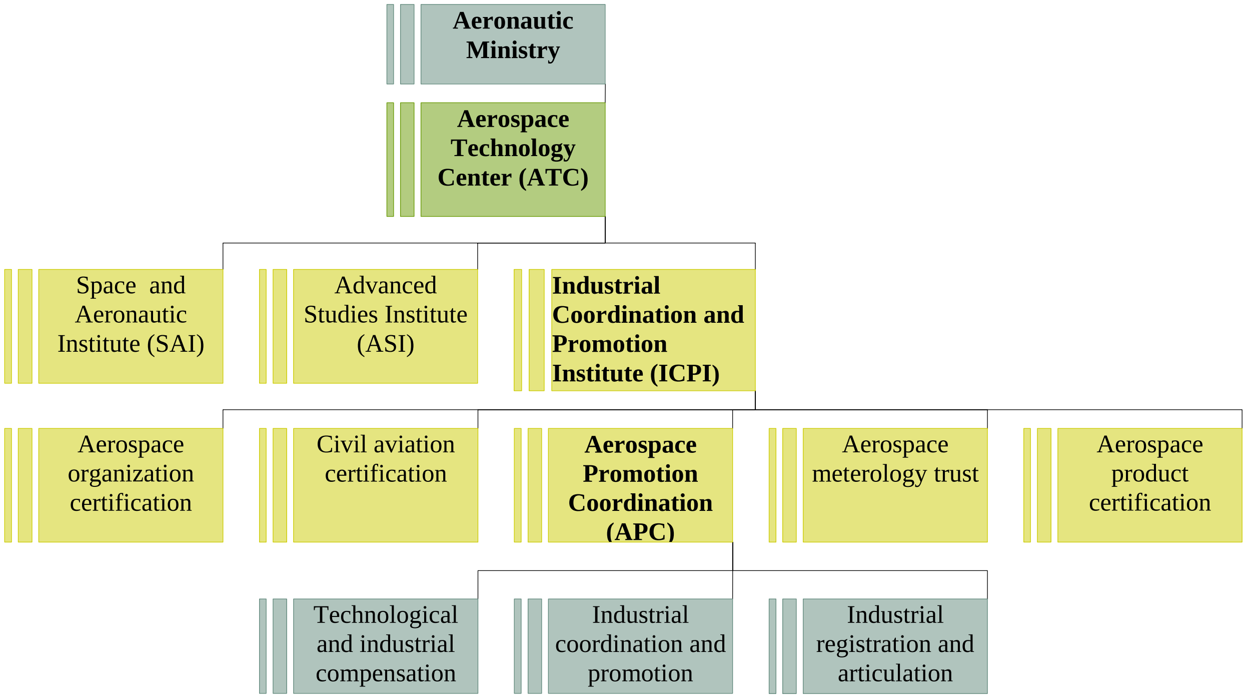

Figure 1 – ATC network hierarchy

In such context, we may consider that the ICPI, and particularly, the APC departments are characterized as being fundamental actors of the S,T&I system for the sector's cooperation network analysis. In other words, the relationship nature and the role of the interaction protocols established by the APC represent important indicators of the characteristics of the brazilian S,T&I network structure.

Upon relationship aspects, the network that ATC established from the APC interface activities is characterized by its extreme hierarchal structure, related to its original culture and military functions. In this context, the structured documents are used as the interaction and communication protocol pattern besides the existence of other interaction protocols such as Internet, Intranet and Extranet (telecommunication technology).

The interaction process context of the network actors is landmarked by the secrecy approach and elevated levels of confidential information (security) that are traditionally required by military culture. Also, necessary infrastructure resources for technology development are scarce because of the dependence of high investments. Besides, the dependency of international suppliers of products and processes; the access restrictions of critical technologies in the market; and, less expressiveness of private aerospace research in Brazil characterize a particular complex context.

5. Research methodology

The methodological framework is based on a unique case study supported by data collection techniques involving a strategic department of one of the most important groups of the Aeronautic Technology Center (ATC) chain, which greatly impacts on competition of the Brazilian aeronautic industry and is responsible for coordinating the interaction among all network actors: the Aerospace Promotion Coordination area (APC) of the Industrial Promotion Institute (IPI).

According to Yin (1998), the case study method has as main characteristic the fact of being generalized to theoretical propositions, and not to populations and universes. The generalization to the theoretical proposition is exactly the subject intended by the work, which turns the case study into the ideal instrument to reach the objective.

A detailed semi-structured questionnaire was created and applied to 20-30 years experienced decision makers, representatives and analysts of the APC area.

The main researched subject was focused on the industrial organizational structure changes coming into place to become more efficient and effective to compete on an environment with continued unexpected events. The research framework of the present article involves the variables discussed in section 2, as for instance:

- Institutional role of the actors in the aeronautic industry network for competition: external and internal clients, suppliers and regulators of the industrial chain;
- New interaction and communication protocols being used between the industry network actors: in presence form and the use of telecommunications technologies form that supports the communication and interaction basis;
- Social and cultural environment changes to stimulate cooperation among private and governmental institutions: organizational hierarchy changes and implications.

Besides, the above aspects were questioned based on changing events during a 20-30 year time range and a short term forecast.

The information obtained through interviews were later grouped together and organized using the logical structure of cooperation networks to redefine the Brazilian aeronautic model of interaction and articulation aimed to guaranty the necessary conditions for its production competitiveness.

6. Conclusion

According to the present study, it can be concluded that the organizational structure of the Brazilian aeronautic sector is moving to a "mixed" network by referencing the main environmental conditions such as the guaranty of the veracity of obtained information and the verification of technical resources required by its unique client – the Brazilian Aeronautic Command (Civil Defense), the historical hierarchal structure of the sector; the predominant industry culture; the precarious and obsolete of telecommunication infrastructure in Brazil; tax regulations; and the recent innovation law (additional responsibility of intellectual property).

This implies to comprehend that this model tends to respond efficiently and effectively to the sector's reality in a short term even though aimed to accomplish long-term strategic objectives for competition.

In this matter, as a contribution from this study, thinking in strategic network models that aim to realize a dream or desire by adopting current practices is fundamental. In other words, strategic network models should be contextual and dynamic.

As one says, "reality is how it is and not the way we want it to be". It is fundamental bring reality into context when presenting a relevant network model for improving efficiency and effectiveness of a specific production process.

Also, this field of study brings new research challenges, as for instance the development of network components and technologies for mobility management, multiple access Internet Protocol (IP) quality of service (QoS), and moving networks (POLITIS, ODA, DIXIT, SCHIEDER, LACH, SMIRNOV, USKELA & TAFAZOLLI, 2004). Therefore, the trajectory for the development of future cooperation networks brings into consideration an evolution of current communication and interaction protocols, new roles (network actors) and social and cultural changes in all network environments.

As future research, the present article suggests to develop a new typology of cooperation network derived from the results of new communication and interaction protocols originated by technological convergence as a new strategy advantage for competition for other regions similar to Brazil.

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