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Transfer of Technology for Successful Integration into the Global Economy

A case study of Embraer in Brazil

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Note

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Preface

The main objective of the studies carried out under the UNCTAD/UNDP Global Programme on Globalization, Liberalization and Sustainable Human Development: Best Practices in Transfer of Technology is to identify factors that could enable firms in developing countries to upgrade technologies or develop new technologies with a view to enhancing their productivity. The case studies focus on successful cases of technology transfer and integration into the world economy. They are thus expected to provide lessons, in terms of *best practices*, to other developing countries in the context of *technological capacity building.*

The project consists of three case studies[1] of sectors where the selected developing countries have demonstrated their ability to create new productive capacities and successfully participate in the world market. Each of the sectors represents an example of *created* comparative advantage; that is, where a country's factor endowments were modified through investment in physical capital, human resources and the building up of capacities to develop and use new technologies. Central to an understanding of the catch-up process and the building of technological capacity across countries is the identification of firm-level factors as well as government policies and institutions that enable firms to thrive, grow and compete in the world market. Therefore the case studies aim to identify conditions under which sectoral development, integration into the global economy, and sustainable human developments are all linked together.

[1] The three case studies are: *A Case Study of the Pharmaceutical Industry in India*; *A Case Study of the South African Automotive Industry*; and *A Case Study of Embraer in Brazil*. These three studies will also be part of a forthcoming publication under the UNCTAD/UNDP GLOBAL PROGRAMME ON GLOBALIZATION, LIBERALIZATION AND SUSTAINABLE HUMAN DEVELOPMENT, which will include overview on the studies and on the international dimension of the national policies adopted in these cases.

INTRODUCTION

It is widely recognized that the capacity to generate and use knowledge is the most important element for sustainable competitiveness and growth of firms and countries. In fact, as emphasized by the evolutionary approach to innovation, knowledge creation and diffusion are fundamental sources of sustainable economic dynamism. Learning, the key source of change, is seen as the most important mechanism for knowledge accumulation, innovation and growth. Firms are obviously at the centre of these processes. However, it is increasingly observed that interactions among them and their interactions with a number of other organizations (dealing with such aspects as education, training, research and development (R&D), financing and policy support) play an important role in the process of knowledge creation and diffusion.

To deal with such complexity the notion of systems of innovation was developed. Furthermore, the concept of national systems of innovation (NSI), which stresses the importance of knowledge and innovation in explaining the economic performance of firms and countries, has become accepted as a useful way to understand the interactions occurring in the process of generation and diffusion of technologies and the institutional diversity which is part and parcel of this process (Freeman, 1987; Lastres, 1994).

However, there have been limited attempts to use the idea of NSI in analyses of developing countries. These have generally taken for granted both the hypotheses and analytical categories elaborated for industrialized countries, with little effort made to qualify the concept and adapt it to the development environment. In fact, until recently, development theory, when considering the possibilities open to developing countries to establish production and participate efficiently in the world market, has focused on comparative wage rates, natural endowments and other related advantages as necessary preconditions. It is true that a number of authors have emphasized the role of technological change in the growth of developed countries. However, development economists have not typically thought of industrialization in terms of technical change, despite the emergence of a large and important body of literature on technical change and development.

The basic aim of this paper is to analyse the recent success of Embraer, the Brazilian aircraft manufacturer, as an example of how innovation systems have been used in a country that are still in its development stage. The paper argues that mastering technical change has always been essential for development, even more important in the present era of world capitalism, known as the Knowledge Era. The analysis of the Brazilian aircraft innovation system is part of an ongoing research project on National and Local Systems of Innovation in the MERCOSUR countries, carried out by several institutions and scholars in the region. The project aims at gathering and analysing information on local productive clusters with a view to contributing to discussions about national systems of innovation in developing countries (characterized by even higher levels of diversity and institutional instability than those of the developed economies).

The paper is organized in the following way. Chapter I discusses the importance of Embraer and the Brazilian aircraft innovation system in the Brazilian economy. Chapter II analyses the development of the Brazilian aircraft industry and related innovation system from their origin in the mid-1940s till the early 1990s when structural changes in Brazil led to Embraer's privatization. This analysis shows that strong and continuous support by the federal Government and the state and a particular technological strategy were essential for the consolidation of the innovation system and the recent success of the company. Chapter III concentrates on a discussion of Embraer's strategy after privatization and chapter IV describes Embraer's recent success based on its understanding of competition in the aircraft market during the 1990s; its productive and innovative strategy is also discussed. Chapter V presents the aircraft innovation system of São José dos Campos, as it is today, pointing out its fragility and strong points. Finally the concluding remarks present policy prospects.

CHAPTER I

THE IMPORTANCE OF EMBRAER AND THE AIRCRAFT INNOVATION SYSTEM IN THE BRAZILIAN ECONOMY

Since the early 1990s, structural reform, through liberalization, deregulation and privatization, has significantly affected innovative behaviour at the microeconomic level in Brazil, with important consequences for its national systems of innovation (NSI). The following are some of these consequences, as suggested in an earlier paper (Cassiolato and Lastres 2000):

- The substitution of imported capital goods for domestically-produced machinery and equipment;
- A significant decline in public expenditure on science and technology (S&T) as a result of structural reform, and particularly privatization;
- Although private agents were expected to play a more important role in technological activities empirical data show that this has not been the case;
- The discontinuation of local engineering activities by subsidiaries of transnational corporations (TNCs);
- Most of the local innovative firms have been acquired by TNC subsidiaries that, as part of their strategies, are downgrading the technological activities carried out locally;
- Independent and public R&D institutes are changing the mix of activities they conduct: they are reducing the number of research projects they undertake and increasing the share of consultancy and technical assistance activities, which provide them with the resources they need.

One of the most significant results of these changes has been that the Brazilian economy has specialized in sectors and areas of relatively low dynamism. As table 1 shows, in 1998 the share of exports of "very dynamic" goods (those in which international trade grew at least 10 per cent in value between 1982-1984 and 1996-1998) in total exports, was 18 per cent in Brazil. Although this pattern is similar to that of other Latin American economies such as Argentina and Chile, it significantly contrasts with the experience of other countries that have benefited from globalization such as the United States (42 per cent of dynamic goods' exports), Japan (55 per cent), Germany (46 per cent), Malaysia (57 per cent) and the Republic of Korea (48 per cent).

In fact, given the specialization pattern of Brazil's economy, its participation in trade flows in new technologies is negligible. Brazil's share of world exports of technology-intensive products (aerospace, informatics, electronics and telecommunications), as defined by OECD, 1996 fell from 0.6 per cent in 1985, to 0.26 per cent in 1991 and 0.19 per cent in 1995. This pattern is similar to that of the other members of the Southern Common Market (MERCOSUR), such as Argentina that witnessed its share decline from 0.08 per cent in 1985 to 0.04 per cent in 1995 (see table 2).

Table 1. Share of exports of "very dynamic" goods* in total exports, selected countries, 1998

Country	%	Country	%
Japan	55	Malaysia	57
United States	42	Korea, Rep. of	48
Germany	46	India	19
France	41	Brazil	18
Spain	40	Argentina	16
Italy	38	Chile	9

*"Very dynamic" are goods for which the world trade grew by at least 10 per cent in value between 1982-1984 and 1996-1998.
Source: IEDI[2] (2000), quoted in *Folha de São Paulo*, 25 April 2000.

Table 2. Total exports of high-tech products, selected groups of countries, 1985-1995 (US$ million and percentage)

	1985		1991		1995	
	$ million	%	$ million	%	$ million	%
European Union	139 795	50.6	136 761	43.1	193 871	38.0
NAFTA*	61 846	22.4	92 054	28.9	121 194	23.7
Latin America (excl. Mexico)	1 959	0.7	1 074	0.3	1 314	0.3
- Brazil	1 697	0.6	817	0.26	982	0.19
- Argentina	232	0.08	221	0.06	222	0.04
Asian tigers**	64 583	23.4	69 777	21.9	149 588	29.3
Australia	423	0.15	709	0.22	1 392	0.27
New Zealand	140	0.05	88	0.03	213	0.04
South Africa	NA		322	0.10	516	0.10
Total	276 237		317 999		510 710	

* NAFTA: North American Free Trade Area, comprising Canada, Mexico and the United States.
** Japan, the Republic of Korea, Taiwan Province of China and Singapore.
Source: European Union (1997)

This downgrading of Brazil's specialization happened during a period when structural reforms were adopted with a view to modernizing the economy and increasing its competitiveness so as to accelerate the country's integration into the globalizing, knowledge-based economy. A strong effort to attract new foreign direct investment (FDI) was an essential component of this strategy, which Brazil aggressively pursued during the 1990s. However, the new FDI of the 1990s was directed mainly at mergers and acquisitions of existing firms rather than at greenfield investment. A recent study which attempted to identify the strategies of TNC subsidiaries that are planning new investments found that they are basically import-intensive and

[2] Instituto de Estudos para o Desenvolvimiento Industrial (IEDI), São Paulo, Brazil.

aim at producing for the internal MERCOSUR market; they are not export-oriented (Laplane, Suzigan and Sarti, 1998).

These two features of FDI in Brazil – relative concentration in acquisitions of local firms and market seeking, import-intensive forms – have had a critical impact on local innovation systems in the high-tech sectors. Several experiences in Brazil illustrate this. For example, in 1996 and 1997 a number of TNCs acquired several large domestic auto-parts producers that were specialized in technology-intensive goods, such as Metal Leve, Freios Varga and Cofap. Subsequently, the R&D activities of the local firms were downgraded, and notably their more advanced R&D was relocated to the parent firms' R&D centres in their home countries.

Even in many of the country's high-tech firms, R&D activities were scaled down when TNCs bought into them, as happened when Alcatel purchased Elebra – one of the most important producers of switching systems – in 1992. In 1999, Zetax and Batik, two domestic firms producing and developing a technologically advanced switching system called Trópico, became part of Lucent Technologies. Interviews indicated that Lucent was not interested in local R&D, preferring to rely on technologies developed in the parent company. A similar process has been observed in other telecommunications TNCs active in Brazil. Since they are increasingly exposed to international competition, they are scaling down local R&D as a cost-reducing strategy. In particular, R&D activities geared to the development of new products is discontinued, with a shift to the more simple adaptation of imported processes and products. In most cases, this has meant that highly qualified engineers engaged in R&D are transferred to other, less-specialized, functions such as production, quality assurance, sales or marketing. A related process observed in the hi-tech telecommunications and information technology clusters in Campinas and São Carlos is that the newly-established affiliates are not linking into locally-based supplier networks. Instead they operate in isolation from the domestic innovation system, preferring to deal with their parent companies and other affiliates rather than with local firms. This too has a negative impact on local R&D capacity.[3]

As a result, the country is losing the competitive edge it had developed in some product markets. This has reinforced a process of increasing import intensity that began with trade liberalization in the early 1990s. For example, the import penetration coefficient for parts and components in the car industry increased from 8 per cent in 1993 to 20–25 per cent in 1996; import penetration in information technology and telecommunications products soared from 29 per cent in 1993 to around 70 per cent in 1996 (Laplane, Suzigan, and Sarti, 1998). If local production of high-tech intermediate inputs in production continues to decline, the share of imports is bound to increase further. The impact on technology would then be reinforced by an adverse impact on the trade balance.

Given the above-mentioned emerging pattern of international system of production, the case of the Brazilian aircraft manufacturer, Embraer, stands out as an admirable exception. As shown in table 2 above, Brazil's total exports of hi-tech products in 1995 amounted to less than a US$ 1 billion **(**US$ 1 = Real$1). According to official statistics (table 4), Embraer was responsible that year for US$ 182 million (i.e. 0.7 per cent) of all manufactured goods exported by Brazil. Four years later, the company became the largest Brazilian exporter, with US$ 1.7

[3]For details, see Cassiolato, Lastres, and Szapiro, 2002; and Szapiro, 2002.

billion worth of foreign sales in 1999 and US$ 2.7 billion in 2000 (table 3); this represented 6.48 per cent of all Brazilian exports of manufactured goods in 1999 (table 4). In 1997, during the Aerospace Fair at Le Bourget, Paris, it signed contracts worth US$ 6.6 billion – a record in the world aeronautics industry. In a period of less than five years Embraer was able to reverse its near bankruptcy to become, in 1998, the world leader in the commuter/regional jet market. It is now the fourth largest Western aeronautics firm, just behind Boeing, the Airbus Consortium, and the Bombardier Group, the latter being its direct competitor. Having designed, developed, produced and commercialized two successful medium-sized aircraft, the ERJ-145 (50 seats) and ERJ-135 (35 seats), Embraer has become the only world player among Brazilian firms in the technology-intensive area. It is also the only important locally-owned firm in this area that has so far resisted acquisition attempts by foreign TNCs.

Table 3. Main Brazilian exporters, 1999 and 2000

	Exports	
Firms	US$ million	
	2 000	1 999
Embraer S/A	2 702.0	1 691.5
Cia Vale do Rio Doce	1 596.1	1 542.1
Petrobras S/A	1 456.5	739.8
Volkswagen do Brazil Ltda	1 128.9	527.4
Bunge Alimentos S/A	976.9	925.6
Cia Siderúrgica Tubarão	948.8	753.9
Fiat Automóveis S/A	622.6	813.4
Motorola Industrial Ltda	597.2	150.9
Aracruz Celulose S/A	587.0	488.3
General Motors do Brazil Ltda	572.6	456.2
Total (10 largest)	11 188.6	8 089.1
Others	43 897.0	39 922.3
Total	55 085.6	48 011.4

Source: Brazil – Secretaria de Comércio Exterior (SECEX), 2000.

Table 4. Brazil: Total exports, exports of manufactured goods and exports of aeroplanes, 1995-1999 (US$ million)

	1995	1996	1997	1998	1999
A. Total exports	45 506	47 747	52 994	51 140	48 011
B. Exports of manufactured goods	25 565	26 413	29 194	29 387	27 329
C. Exports of aeroplanes	182	284	681	1 159	1 772
D. C/B	0.71	1.08	2.33	3.94	6.48

Source: Brazil – Secretaria de Comércio Exterior (SECEX), 2000.

Embraer's remarkable recent success is certainly the result of deep restructuring processes in production and business following its privatization in the 1990s. However, most importantly, it is also the result of long-term government-sponsored institutional and technological developments that date back to the 1950s. The next chapter discusses the origins and historical development of the Brazilian aircraft industry.

CHAPTER II

DEVELOPMENT OF THE BRAZILIAN AIRCRAFT INDUSTRY UP TO PRIVATIZATION: STATE SUPPORT AND TECHNOLOGY STRATEGY

Brazilian aircraft production is concentrated in the São José dos Campos region of São Paulo state, which is where Embraer is located. São José dos Campos is 80 kilometres from the city of São Paulo. According to official statistics for 1996, this region was responsible for 6 per cent of the value added, 3 per cent of the total number of firms, and 4 per cent of the industrial workforce of São Paulo state.

Chart 1 presents the most important events that have affected the evolution of the Brazilian aircraft industry (BAI). In fact, the origins of this industry can be traced back to the setting up of the Aeronautic Technology Centre (CTA) in 1945 as an institution of the Ministry of Aeronautics, which was created four years earlier. The Centre was initially made possible through a cooperation agreement with the Massachusetts Institute of Technology (MIT), United States. In 1947, CTA set up the first undergraduate school, Aeronautics Technological Institute (ITA), with the aim of training specialized engineers and it has been one of the best engineering schools in Brazil.

At the beginning CTA and ITA were located in Rio de Janeiro, which was Brazil's capital at that time. However in 1950 they were transferred to São José dos Campos. In the mid-1950s CTA began research activities with the setting up of the Institute of Research and Development ((IPD, in Portuguese) for undertaking research in some basic areas related to aeronautics (aircraft projects, electronics, materials, engines and flights tests). One of the first technology projects, by IPD's Department of Engines, aimed at improving jet-propulsion engines. In 1954 an ambitious project, the Convertplane, was also conceived, aimed at designing an aeroplane with a vertical take-off propeller and a horizontal flight trajectory, to be used as a conventional plane. This resulted in the prototype of BF-1 (*Beija Flor*), a two-seater helicopter.

The main idea behind the setting up of a technology centre (CTA) and an institution (ITA) devoted to training high-quality engineers, modelled on MIT (ITA), was to establish, develop and acquire skills and capabilities in aircraft manufacture. In fact, since the creation of CTA, Brazilian policy had envisaged the setting up of a national aircraft industry as the ultimate goal for the sector. CTA was to occupy a central place in the strategy, as it would foster the development of the requisite human resources and technological capabilities. And the setting up of Embraer as a State-owned manufacturer of aircraft, under the Ministry of Aeronautics was a natural outcome of these earlier developments. State actions and policies, unprecedented in Brazil's technological and industrial history, which used tax incentives and benefits, procurement, and continuous government support, enabled the recent successes of the country's modern aircraft industry.

Embraer was conceived as a State-owned company that would concentrate its efforts on the assembly of aeroplanes. The important point about Embraer's initial plans was that the local manufacture of aeroplanes was to be undertaken through aircraft projects designed and conceived in Brazil by Brazilian engineers and technicians. The basic concept behind the plan was the

acquisition of "technological autonomy", meaning the capacity to understand the whole technological cycle of aircraft production by developing and manufacturing it. It is worth pointing out that this concept was similarly used in some other areas where the Government had played an important role in the 1950s and 1960s, such as oil production (with Petrobras) and even car manufacture (with FNM).[4]

In 1969 Embraer was set up as a government-controlled enterprise (Sociedade de Economia Mista), with the Brazilian Government keeping at least 51 per cent of the voting capital. It commenced its manufacturing activities in January 1970 with a staff of 150 employees, all recruited from CTA (more specifically IPD). Blue-collar workers were recruited mainly from the automobile industry, which had been set up in Brazil in the late 1950s. The initial capital subscribed by the federal Government was about 5 million cruzeiros (around US$ 1 million).

Given its size, Brazil used to be a large importer of small aeroplanes (up to 10 seats) from the United States. During its early stages, Embraer signed a manufacture cooperation agreement with the PIPER Aircraft Company of the United States to carry out production of an import substitution kind. In 1971, its first aircraft, the Ipanema, was launched; it was designed for civilian use, specifically the agricultural market. Also that year, Xavante – an aeroplane designed for the military market – was launched. The Xavante project was developed through a licensing agreement with an Italian firm, Aermacchi. In 1973, Embraer's most successful aircraft, the 19-seater Bandeirantes, was launched, intended for both the civil and military markets.

From the late 1970s to the late 1980s Embraer successfully embarked on several ventures. In 1978, Xingu and Tucano aircraft directed at the Brazilian market were launched. In 1981 the Brasilia aircraft project was relaunched. This aircraft was intended to be an improvement on the successful Bandeirantes, while using the same basic technologies.

In 1980 another project, the AMX, to manufacture a military aircraft, was set up as a joint venture with Italian firms: Aeritália (with a 46 per cent share) and Macchi Aeronautic (with 24 per cent), and Embraer had a 30 per cent share. Embraer also entered into an agreement with Argentina in 1989 for the 12-X project, a prototype aimed at replacing the Bandeirantes, as part of the political agreement between the two countries, which culminated the creation of MERCOSUR. However, this project turned out to be Embraer's biggest failure.

It was also in 1989 that the development of what would become its biggest success started: the ERJ-145 was to be the first jet produced by Embraer. It was a project conceived under the so-called "communality" concept that in fact meant designing a jet aeroplane using similar basic concepts as the previous turboprop technology, with many components common to the Brasilia and CBA-123.

Embraer has conquered the regional air transport market, both in Brazil and internationally, with its EMB-110 Bandeirante for 19 passengers, and, more recently, the EMB-120 Brasilia for 30 passengers. Both turboprop aeroplanes acquired an international reputation

[4] The project of manufacturing a locally-developed car with FNM was subsequently abandoned when foreign-owned car assemblers were chosen to lead the Brazilian strategy in the area. In fact when Volkswagen of Germany acquired FNM in the early 1960s the project was scrapped.

becoming leaders in the United States market in their category. As a matter of fact, in the early 1990s, the Brasilia had a 24 per cent share of the world market for aircraft of the same category (Dagnino, 1987).

Embraer's success in technology and innovative development was exceptional and unprecedented in Brazil's industrial history. It should be pointed out that crucial to this success was the technology developed by the IPD. Although license and cooperation agreements with foreign firms were essential for the success of Embraer, the origins of the three projects (the EMB-110 Bandeirantes, the IPD-6909 Ipanema and the EMB-326 Xavante) can be traced to IPD in the late 1950s. In fact most products, technologies and human resources that became the backbone of Embraer originated in IPD. Embraer absorbed this technology in the simplest way: by hiring all IPD personnel when the company was created. The entire technical team, administrative personnel and of almost all of IPD's Aircraft Department (and other smaller departments) were assigned to Embraer (Pasqualucci, 1986:41). It attracted qualified labour by offering favourable working conditions, and a good salary and career prospects. However, the acquisition by Embraer of what was important in IPD, insofar as technological know-how was concerned, led to a virtual "hollowing out" of that Institute. Practically two decades elapsed between the end of the project developed in the 1960s and the beginning of new research of any significant technological content in IPD, namely the development of an unmanned aircraft (Cabral and Braga, 1986).

Embraer focused its efforts on those key technologies that define the aeroplane as a final product. It was a significant departure from the dreams of the 1930s and 1940s of building a totally national aeroplane, with motors, components, parts and avionics made in Brazil. The company strategically favoured a technology strategy towards capacity training in the areas of aerodynamics, fuselage and project integration. Efforts were directed towards training and developing capabilities in two basic areas: the aircraft project and the integration of components that could not be manufactured by Embraer itself. The reasons behind this important decision not to organize production vertically were basically scale, market size, reliability and technical difficulties.

The acquisition of technical competence for the fuselage of the aircraft was considered to be strategic for the competitive future of the company. According to interviews with senior officers of Embraer**,** competence in fuselage "was the only key area in which the know-how required could not be obtained satisfactorily outside the Brazilian borders". This was considered an essential condition for autonomy in product design and for the eventual success of the firm as a competent final assembler of aircraft. As experience would show, this approach proved to be essential to Embraer's future, since this gave it independence and autonomy of decision-making. It enabled Embraer to master the basic technologies of the aeronautical industry, manage its own business, and create market opportunities. "It was more important for the commercial success of the company than the control of the most sophisticated and numerous technologies that the production of an aircraft requires and of the other thousands of items that comprise it" (Dagnino, 1987).

Thus, the strategy outlined for the company, was based on the premise that the capacity to master technology through systems integration was more crucial than having a larger share of the value-added of the aircraft being produced in Brazil. It is worth pointing out here that most of the

Brazilian industrialization through import substitution was based in the idea of increasing local production. According to Dagnino (1994), if the public authorities of the aeronautical sector had pursued the illusion of increasing local content, approximately 50 per cent of local value added could have been reached by the mid-1980s. However, to attain this goal and, at the same time to complete the mastering of technology, the Brazilian strategy would have had to be entirely different and it probably would have been impossible to achieve both the goals. Costs probably would have been prohibitive and the time span required to successfully enter the market would surely have been longer. In fact under such a strategy Brazil should have pursued the reproduction of the entire development cycle of aircraft found in developed countries. It is enough to highlight, for example, that there are no more than five countries manufacturing aeronautical motors with own technology.

The fundamental notion behind Embraer's strategy was to target key areas responsible for all basic technological development, supporting incremental technical change and building core competence. This distinctive perception about accumulation of productive and technological capabilities was vital to the success of its strategy. It led the company to identify "key technologies" necessary for a progressive technological upgrading, and included essential technologies for the future as, for instance, new materials.

The most important aspect of this strategy is that it allows for the independent conception of projects. In a similar vein, by adopting the concept of "aircraft families", used both by Boeing and Airbus for their big commercial jet lines, Embraer acquired the benefits derived from the development of several versions of the same basic models, which entailed lower costs, faster development and a shortening of the production cycle. A "family" has the advantage of a common concept that brings lower infrastructure and maintenance costs, standardized pilot and technical personnel training and common crew upgrade possibilities; In short, lower costs and faster aircraft production. This allowed for a reduction in the time-to-market, to about two or three years, less than half the time that a new project usually takes. This concept was applied in the development of several aeroplanes, such as the Bandeirante, Xingu, Brasília, CBA-123 and ERJ-145, some of which became great commercial successes in the world commuter aviation market and brought recognition, prestige and fame to the company.

These three approaches – the "family" concept that permitted the drawing of benefits from common resources; cumulative paths and coherence in the organizational and technological training of high complexity, allowing identification of the critical key technologies that foster improvement and appropriation; and the strategy of vigorous investment in training of human resources – formed the backbone of Embraer's pursuit of technological autonomy.

Chart 1. The main events in the evolution of the aircraft production system of São José dos Campos 1947–1999

- 1947 – Construction of the Aeronautic Technical Centre (CTA) begins. The planning and construction is supervised by OCATC (Organizational Commission of the Aeronautics Technical Centre) of the Aeronautics Ministry, established on 29 January 1946 and disbanded on 26 November 1953.
- 1950 – CTA and its engineering school, ITA (Aeronautic Technological Institute created in 1947) are transferred from Rio de Janeiro to São José dos Campos. The students are scholarship holders sponsored by the Ministry of Aeronautics; besides free tuition they get free lodging, food and health care. It is a developmental milestone in university education in Brazil.
- 1954 – The Institute of Research and Development (IRD) is set up at CTA with the aim of developing research in basic areas for aeronautics (aircraft project, electronics, materials, engines and flights tests).
- 1954 - Convertplane project set up.
- 1969 – Embraer set up.
- 1970 – Embraer starts manufacturing activities.
- 1971 – The Ipanema and Xavante are launched.
- 1973 - The Bandeirantes is launched.
- 1974 – Cooperative agreement with the US PIPER Aircraft Company is signed.
- 1978 –Xingu and Tucano aircrafts are launched.
- 1980 – Development of the AMX programme begins.
- 1981 – The Brasilia aircraft project is relaunched.
- 1989 – Development of the12-X project (Brazil-Argentina's Cooperative Agreement) begins.
- 1989 – Studies for the development for ERJ-145, (first jet produced by Embraer) begin.
- 1992 – Embraer is included in the national privatization programme.
- 1994 – Embraer is privatized
- 1996 – Two hundred ERJ-145 are sold at the Farnborough Air Fair in the United Kingdom.
- 1997 – After a dramatic dispute with the Bombardier group, Embraer gets the largest contract in its history at Le Bourget Aeronautic Fair, in France.
- 1997 - Development of a new regional jet, the ERJ-135 for 37 passengers, begins.
- 1998 – Development of a new regional jet, the ERJ-140 for 40 passengers, begins.
- 1999:

  – Development of a new family of regional jets, the ERJ-170/190, begins.

  – Twenty per cent of Embraer's ordinary shares are acquired by a French consortium led by Aérospatiale Matra, Dassault Aviation, Thompson-CSF and Snecma.

  – The new families of regional jets and military products are presented to the market.

  – The Swiss company Crossair becomes the first Embraer client for the ERJ-170/190 programme. At Le Bourget Fair, a contract worth US$ 4.9 billion, for 200 jets, is signed.

Source: Embraer

The company outlined a strategy regarding not only the *know-how*, but also, especially, the "*know-why",* concerning training processes and technological innovation, since it was a State-owned company. In that sense, as Dagnino (1987) pointed out, the solid and continuous government support offered to Embraer throughout its history differed from the experiences of other countries. This support was given through budgetary allocation of sufficient financial resources for the science and technology (S&T) infrastructure and procurement. According to Dagnino, the main axis in the technological strategy adopted by Embraer was not the import of "technological packages" ("black boxes"), to be subsequently "opened" and adapted to local conditions and eventually optimized by "reverse engineering". On the contrary, investment and efforts were directed towards developing competencies by providing solid training in applied and basic research and by continuous concern with training to enhance capabilities and skills in the development and design of specific technological solutions, through consulting services and technology agreements. This was the road chosen to increase the innovative potential of the firm. Typically, Embraer followed what is known in the literature as a "learning strategy". The learning was mainly of the "learning by doing" type, but sometimes it was also of the "learning by adapting" kind. The process of "learning by doing" characterized the first period of the company. Starting from training in aeronautical projects (especially in aerodynamics) it was possible not only to assimilate the remaining know-how – not specifically technological – but also to open up organizational learning paths. This endowed the company with a capability to formalize problems and solutions, which was crucial for the process of aircraft certification.

It should be added that other ways of learning through recruiting ("learning by hiring") and subcontracting ("learning by interacting") were important. The former was obtained both by association with outside partners and by government policy, particularly from the Ministry of Aeronautics, through procurement. A good example was the decision by the Ministry of the Aeronautics to equip the Brazilian Air Force with MB-326 aeroplanes in the late 1970s. Instead of buying these aeroplanes in the international market, the Ministry sought to develop local production. As a result Embraer signed an agreement with the Italian Aermacchi for production of the Xavante military aeroplane. The development of the project required several Italian specialists to come to Brazil for helping local production and for the transfer of technology. Another example was the agreement Embraer set up with Piper, which used to sell aeroplanes in Brazil before the Ministry of Aeronautics established rules that imposed, in practice, a market reserve.

Other important agreements signed by Embraer that had a significant impact on the development of its human resources capabilities were:

a) Technical assistance and aircraft maintenance agreements with airline operators; and

b) Manufacturing of complex components by order (with McDonnnell Douglas and Boeing).

Finally, Brazil's Air Force bought the F-5s from Northrop Grumman of the United States, and the Ministry of Aeronautics included, as part of the sales package, a technological training programme for Embraer in the areas of metal welding, composite materials and in the use of digitally-controlled machines (Dagnino, 1994).

Learning through user/supplier interaction was intense and global. Embraer became known in the world market as being a user of extremely qualified equipment and software. It was

not satisfied in simply knowing how to operate services or technology that it acquired, but, above all, the company aimed at modifying the technology to its requirements. In many cases, this led to improving, correcting defects, and even opening up new market opportunities for the product. Embraer also became an active and highly qualified technology user, with significant gains from "learning by using." It distinguished itself for its long-term strategy and for its training programmes and for its employees' professional education in general. The excellence of its human resources was always considered a critical factor to its successful growth. And in that sense, the importance and the strategic focus of the company on learning by training was crucial. In the early years of the company, during the process of the transfer of technology for production of the Xavante programme, about 70 employees were trained in Italy. Thus the company was able to proceed rapidly from assembly operations to the national production of this aeroplane. Especially relevant were the partnerships for the training of personnel, developed with the AMX programmes and later, in the 1990s with the ERJ-145 programme.

To sum up, the federal Government supported and promoted a coherent, cumulative and continuous technological policy, which targeted Embraer, the S&T infrastructure in São José dos Campos and strong interaction among the several institutes of CTA and Embraer itself. In practice it allowed Embraer to obtain technological training and a quite uncommon competitive position in relation to other developing countries. However, it is interesting to note that although this phase of the aircraft industry in Brazil was characterized by a strategy of development, learning and consistent and successful technological training, where active forms of technological learning were identified, there were some pitfalls. Embraer experienced a crisis in the early 1990s, but quickly recovered. The next chapter discusses this recent period.

CHAPTER III

THE 1990s: CRISIS, PRIVATIZATION AND RECOVERY

The economic and political crisis in Brazil at the end of the 1980s and the first half of the 1990s deeply affected Embraer and the entire Brazilian economy. This general crisis was aggravated by world crises in the aerospace and defence industries. However, the second half of 1990s saw recovery, and a new investment and economic growth cycle was inaugurated.

The roots of this crisis were to be found in the previous decade. Macroeconomic problems were associated with a significant decrease in government spending. A sharp reduction in the R&D budget and a progressive weakening of the scientific and technological infrastructure had a significant impact on the aircraft innovation system. Procurement also diminished, since the budget crisis meant fewer funds for government purchases in the aeronautic, space and defence sectors.

During the crisis, federal industrial and technological policies virtually disappeared. Several financing mechanisms normally used to support aircraft sales were scrapped. Also, as an outcome of the democratization process, the military – that constituted a powerful pressure group for Embraer's interests – lost its political clout. On the external front, the recession in the regional aviation market and the end of the Cold War strongly affected Embraer. At the microeconomic level, Embraer rapidly experienced financial troubles for the following reasons:

- It had started several new big projects without appropriate financial backing. The overall economic crisis also meant that even the few private financial institutions that were willing to give long-term credits were charging very high interest. Embraer, being a State-owned company, had to submit all its financial dealings to the national Congress. This was a long and uncertain process, and Congress seldom gave authorization for loans. Therefore, the Company was forced to seek short-term loans that charged much higher interest rates. As a result its financial problems spiralled;
- Projects were developed without detailed market research and a thorough examination of potential clients' needs;
- Embraer's management was excessively technology-driven, focusing more on technological capabilities and product development than on financial matters; and
- as a result, cost considerations were not given a high priority.

The final result was a rapid loss of competitiveness in both internal and external markets. In the internal market the situation was aggravated by the fact that the Government not only stopped its financial backing of Embraer, but also opened the economy to international competition in a way that favoured imports. Also, macroeconomic instability led to high interest rates, as mentioned above, that made loans more expensive.

Brazil's economy in the first half of the 1990s was marked by structural reforms and macroeconomic stabilization plans based on the free-market concept, accompanied by the dismantling of policies for financing industrial, technological and export growth; for example, in 1991, as part of a wider reform process, the federal Government ended the programme, Finex, which aimed at providing long-term finance for Brazilian exports. Furthermore, a decline in

government orders and a drastic reduction in employment and manufacturing resulted in a loss of the country's competitive position both on the domestic and world markets.

In the early 1990s, the recession in the world aircraft market affected EMB-120 Brasilia aircraft sales. Moreover, Embraer's own problems contributed to the rise in financial costs, with a direct impact on the price of the aircraft. There were already clear signs of preference for jet aircraft. From the buyer's point of view, lack of competitive credit lines for export was another negative factor affecting aeroplane sales. An example of the negative repercussion of the crisis experienced by the company on its international prospects was the loss of an important public tender in the United States, called JPATS (Joint Primary Aircraft system). This was a tender for the supply of 711 training aeroplanes to the United States Air Force and Navy worth US$ 7 billion. Embraer spent years preparing itself for this tender with the Super Tucano turboprop, in consortium with Northrop of the United States. It lost to the Swiss Pilatus PC9, associated with United States Beechcraft that is part of the Raytheon group (which had won the bid for the Amazonian Surveillance System – Sivam - installation in Brazil).

According to specialists, from the technical standpoint the Super Tucano and Pilatus are equal. The Embraer aeroplane had already been chosen in other tender competitions in the United Kingdom, France and Egypt against its Swiss competitor. Another competitor in the JPATS tender along with Embraer and the Raytheon/Beechcraft entry, Pilatus, was Cessna of the United States with its Citation jet. These latter two companies were preferred because they already supplied aeroplanes to the United States Navy and Air Force. The JPATS contract was destined to replace the Navy's Beechcraft T-34 and the Air Force's Cessna T-37. Some analysts have attributed Embraer's crisis to its losing this contract. This loss also affected its credibility and left it in an even more vulnerable financial position. One important result was that the company cut its workforce by half. Approximately 13,000 highly specialized jobs related to the aerospace sector were eliminated; Embraer alone was responsible for the elimination of 8,000 jobs.

In 1992, as part of the deep structural changes undertaken in Brazil, Embraer was included in the national privatization programme. It is important to point out that the costs of retrenchment of the workforce and administrative restructuring, in the most dramatic phase just before Embraer's privatization, were borne by the Brazilian federal Government. After that, the company was ready to be offered to the private sector, and was eventually privatized on 7 December 1994. It was acquired for US$ 265 million by a consortium of local enterprises and pension funds led by the Bozano Simonsen Group, one of the leading Brazilian conglomerates, which operates in the financial, mineral, real state, agricultural and manufacturing sectors. The consortium acquired 40 per cent of the voting capital. Among the main investors were: Bozano Simonsen Limited (13.65 per cent), Bozano Leasing (3.63 per cent), the pension fund, Sistel (10.42 per cent), Previ (10.40 per cent), and Cesp Foundation (1.9 per cent). Ten per cent of the shares were reserved for the company's employees.. The privatization of the company implied further organizational restructuring. Downsizing of production processes was envisaged and some qualified personnel were made redundant.

These changes in Embraer bore fruit when, at the Farnborough Fair in the United Kingdom in 1996, 200 ERJ-145 (its new jet aircraft) were sold to the United States carrier, Continental Express. The strategy to produce this new aircraft proved to be successful. In 1997, at Le Bourget Aeronautic Fair in France, Embraer, after a dramatic dispute with the Bombardier

group, landed the largest contract in its history. This contract was worth around US$ 1 billion for the sale of 67 ERJ-145 jets to American Eagle, the regional airline subsidiary of American Airlines. The new contract also included replacement parts and technical assistance, with firm sales reaching US$ 1.6 billion and options adding another US$ 4 billion over a seven-year period. The contract represented the consolidation of the recovery process and restored the company on the international market. In addition, it allowed for the financial recovery of Embraer and ensured production of aircraft during the subsequent three years. Also in 1997, Embraer started the development a new regional jet, the ERJ-135 for 37 passengers, and the ERJ-140 for 40 passengers.

In short, Embraer was able to rapidly overcome an adverse situation and avoid bankruptcy. It achieved important and successful sales with its two main medium-sized aircraft: ERJ-145 (50 seats) and ERJ-135, and became, in 1998, the world's leader in jet sales. The contracts of US$ 6.6 billion, made during the Aerospace Fair, in Le Bourget, Paris, represented a record in the world's airspace industry. At the time, Embraer was building 22 aircraft models, conducting strategic programmes for the national defence sector, commercializing more than 5,200 aeroplanes in more than 40 countries, and it had approximately 8,000 employees in Brazil. In 1999, the foreign market accounted for 98 per cent of Embraer's revenues, and revenues by segment were distributed as follows: commercial activities accounted for 85 per cent, defence 7 per cent, and spare parts and services 8 per cent (see table 5).

The new family of regional jets (ERJ-170, ERJ-190-100 and ERJ-200 for 70, 98 and 108 passengers respectively) was introduced into the market in 1999, requiring about US$ 850 million for their development. The importance of this new family of products was that it would compete on a different market of larger aircraft, which so far had been the domain of Boeing, McDonnell Douglas and Airbus. The new military products were also presented – the ERJ-145 AEW&C and ERJ-145 RS and ALX. The Swiss company Crossair became the first Embraer client for the ERJ-170/190 programme. At Le Bourget Fair that year a contract worth US$ 4.9 billion, for 200 jets, was signed. On 23 July 1999, as part of a strategy of accessing new technologies, products and markets, 20 per cent of Embraer's shares were sold to a French consortium led by Aerospatiale Matra (5.67 per cent), Dassault Aviation (5.67 per cent), Thomson-CSF (5.67 per cent) and Snecma (2.99 per cent). Shareholder control remained with the Brazilian Bozano Simonsen Group (20 per cent) and the pension funds Previ (20 per cent) and Sistel (20 per cent), the Brazilian Government (3.2 per cent) and other companies (16.7 per cent). The main objective of this new strategic alliance was to double its customer base and open up new possibilities of international financing. This would include setting up in China, considered to be the fastest growing market in the world. Moreover, Embraer aimed at emerging markets, the acquisition of business expertise, commercial and logistic infrastructure as well as critical technologies in the civil and military area, increased installed capacity and a larger scale of production. Also in 1999, Embraer launched a new 44-passenger regional jet, the ERJ-140, a variant of the ERJ-145 family. At the same time, it consolidated its name in the world market as the leader in the commuter segment.

Table 5. Indicators of Embraer's financial performance (Million real)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gross revenue	582	402	333	261	177	295	380	833	1.581	3.379
Sales										
Foreign market. (%)	37	32	32	38	40	39	35	84	89	98
Domestic market (%)	63	68	68	62	60	61	65	16	11	2
Total assets	1 092	1 435	1 227	1 125	1 067	1 107	1 221	1 424	2 618	3 717
Equity	126	324	86	156	281	188	281	-	420	697
Losses/profit	(265)	(241)	(258)	(116)	(310)	(253)	(123)	(33)	132	412
Debt										
General (%)	88.3	77.2	93.6	86.2	73.6	82.2	71.2	45.8	51.5	
General	620	804	877	758	410	470	535	382	379	305
Short-term	502	241	309	394	221	226	214	251	-	-
Long-term	118	563	568	364	189	244	321	131	-	-
Backlog (US$ million)	-	-	-	-	647	729	1 227	3 011	4 112	6 367

Source: Embraer

As shown in table 6, by 1999 Embraer had captured a 40.5 per cent share of the world market, slightly ahead of its main competitor Bombardier (38.5 per cent) and well ahead of Fairchild Dornier (19.9 per cent) and British Aeroespace (1.1 per cent). Embraer and Bombardier of Canada are the main competitors in these important segments of the jet aircraft sector. Tables 7 and 8 below provide some general comparative information regarding both companies and their most competitive products as for years 1999 and 2000. A fierce competitive battle between these two firms began five years ago. The competitive position of Embraer has been based on radical changes in its strategy in the 1990s, resulting in its becoming leader in a network of firms participating in a chain of production. Chapter IV analyses these changes.

Table 6. Embraer's share of sales in the world market for jet aircraft, 1999

MODEL	SEATS	SALES		DELIVERIES		BACKLOG	
EMBRAER		Quant.	%	Quant.	%	Quant.	%
ERJ-135	37	6	1.1	16	7.4	124	13.6
ERJ-145	50	125	22.5	81	37.3	176	19.3
ERJ-170	70	40	7.2	-	0.0	40	4.4
ERJ-190/200	108	30	5.4	-	0.0	30	3.3
TOTAL		201	36.2	97	44.7	370	40.5
BOMBARDIER							
CRJ 100/200	50	172	30.9	82	37.8	253	27.7
CRJ 700	70	3	0.5	0	0.0	99	10.8
TOTAL		175	31.4	82	37.8	352	38.5
FAIRCHILD DORNIER							
328 JET	32	78	14.0	15	6.9	82	9.0
428 JET	44	40	7.2	-	0.0	40	4.4
728 JET	70	60	10.8	-	0.0	60	6.6
TOTAL		178	32.0	15	6.9	182	19.9
BRITISH AEROSPACE							
RJ 85	32	2	0.3	11	5.1	7	0.8
RJ 100	44	2	0.3	12	5.5	3	0.3
TOTAL				23	10.6	10	1.1
TOTAL		556	100.0	217	100.0	914	100.0

Source: Embraer

Table 7. General indicators for the Embraer and Bombardier Groups

Bombardier Aerospace Group	Embraer Group
Set up in December 1986 Gross revenues (1999): US$ 4.412 billion Profits (1999): US$ 467 million Headquarters: Dorval, Québec (Canada) Main Products, Feb 2000: Regional Jets Regional jets represent 80% of total revenues: • Series 100 (version of 50 seats) • Series 200 (50 seats) • Series 700 (70 seats): in development Number of employees (1999): 34 000	Set up in August 1969 Gross Revenues (1999): US$ 1.889 billion Profits (1999): US$ 230 million Headquarters: São José dos Campos, São Paulo, (Brazil) Main Products, Feb 2000: Regional Jets Regional jets represent 85% of total revenues: • ERJ-135 (37 seats) • ERJ-140: (40 seats) • ERJ-145: (50 seats) • ERJ-170: (70 seats) • ERJ-190-200 (108 seats) Number of employees (1999): 9 000

Source: Embraer and Bombardier.

Table 8. Comparisons of the most competitive models of Embraer and Bombardier planes

	Embraer	Bombardier
Model	ERJ-145	CRJ-200
Capacity	50 passengers	50 passengers
Engines	2 turbofans Rolls-Royce AE-300	2 turbofans General Electric CF34-3B1
First flight	1995	1992
Basic price	US$ 18.5 million	US$ 21 million
Maximum speed	833 km/h	860 km/h
Basic weight	12 007 kg	13 740 kg
Operational cost (in 400nm[5])	US$ 2 613.00	US$ 2 832.00
Cost by seat	US$ 7.05	US$ 7 065

Source: Embraer and Bombardier

[5] Nan o meter: one billionth (10^9) of a meter.

CHAPTER IV

UNDERSTANDING EMBRAER'S RECENT SUCCESS

Throughout the 1990s, Embraer and the aircraft production system became increasingly important for the Brazilian economic and industrial structure. It also became the largest Brazilian exporter during this period. Table 9 shows that sales of the aeronautical sector jumped from 0.2 per cent of GDP in 1996 to 1.1 per cent in 2000. It is estimated that in 2002 the sector will account for sales of around US$ 4.2 billion, representing 1.2 per cent of Brazil's industrial gross domestic product (GDP).

Two interconnected reasons explain this extraordinary success. First, and most importantly, the sector has received continuous government commitment and support for more than 40 years. Second, important strategic decisions were taken after privatization which were possible thanks to the previous innovative strategies that Embraer pursued in its first 20 years. It is worth analysing some of the main factors behind this success.

Table 9 - Importance of the aeronautical sector in the Brazilian economy

Economic indicators	1996	1997	2000	2002
Industrial GDP (US$ billion)	317	277.7	321.4	362
Sales of the aeronautical sector (US$ billion)	0.6	0.8	3.4	4.2
Share of the sector in industrial GDP (%)	0.22	0.29	1.06	1.16
Exports (US$ billion)	0.2	0.7	2.5	3.1

Source: Bernandes (2000).

1. Competition in the aircraft market during the 1990s

The international market for aircraft is divided in two main segments: civil and military. Both have very differentiated productive, economic, technological and logistic dynamics. The civil segment has several important competitiveness factors (chart 2). Some of them are internal to the firm, such as design, trademark, R&D, marketing and human resources, while others relate to product and markets. However the industrial structure and the incentive and regulatory regime play a very important role. In general the world market for aircraft may be classified into four different segments. The first refers to large-sized aircraft (more than 120 seats - both for cargo and passengers transport). This is the most profitable market, led by Boeing and by the Airbus European Consortium. This segment can be divided in four groups: 111 and 125 seats, 150 and 175 seats; 210 and 250 seats; 300, 350 and 400 seats; and more than 400 seats.

The second is related to medium-sized aircraft (10 to 120 seats). This "commuters" market, which is covered by regional air traffic companies concentrates on short/medium distances, connections to long distances. Embraer and Bombardier have become the only competitors in this market after some other key rivals went bankrupt in the 1990s. Small-sized

aircraft constitute the third segment. This is the market covering business, sports, agriculture and other related needs. It is a more segmented market characterized by a relatively large number of producing firms catering for different market niches. Finally there is the market for aircraft for corporate use. Here, the aircraft are not used for profitable and commercial purposes, but for transporting executives and clients of big businesses; it is a special area of the small-sized aircraft segment.

Chart 2. Critical factors of competitiveness in the civil aircraft industry

Internal to the enterprise	• Trademark
	• Design
	• Fostering R&D
	• Focus on strategic competence
	• Market intelligence:
	  • Logistics
	  • Productivity
	  • Marketing
	  • Human resource
	  • Technical support
	  • Financing structure

Product	• Image • Time-to-market • Innovation • Aversion factor to different types of engines • Family concept • Communal concept • Seats acquisition cost • Operational costs (seats/covered distance) • Performance/delivery
Market	• Concentrated structure/differentiated oligopoly • Market niches • Substitute turboprop aircraft for jet propulsion systems • Technical segmentation needs • Restricted and selective buyers • Catering to clients' specific requests • Global
Industrial configuration	• Strategic alliances • Specialized economy • Users' interaction • Strong scientific and technological system
Incentives and regulatory regime	• Support to technological risk and to R&D • Government subsidy • Customs and associated incentives • Selective protection • Government procurement • Users' credit and exportation financing

Source: Bernardes (2000)

A high degree of internationalization of markets characterizes all these segments. This specificity of competition in aircrafts is related to two points. First, apart from the United States, there is no single country with a sufficiently large and dynamic internal market to support R&D costs to manufacture a large-sized aircraft. Secondly, the rigid safety requirements and performance parameters needed for certifying aircrafts (without which they are not allowed to fly) are internationally agreed, rendering any production geared only to the internal market impracticable.[6]

An event that radically modified the aircraft market in the last 20 years was the growth of the "commuters'" market based on jet propulsion. Market forecasting for the United States suggests that over the next 10 years, medium-sized aircraft will replace large ones in this market (Boeing, 2001). Embraer's new regional jet family (ERJ-145 and ERJ-135) targets precisely this type of market, which favours quieter and faster aeroplanes (as compared to older turboprop aircraft) larger autonomy to perform non-stop flights and more stability in the case of turbulence.

2. Embraer's production and innovative strategy

Table 10, below, summarizes Embraer's aircraft production from 1980 to 1999. It shows that during the 1990s the jet aircraft has gradually replaced the turboprop aircraft. In fact between 1997 and 1999, the new family of regional jets (ERJ –145 and ERJ -135) accounted for more than 60 per cent (195 units) of the total of 310 aircraft produced. This type of aircraft has become the most important marketable good for Embraer. However, the company still maintains a wide range of products and related services as its core business (see box I).

Table 10. Embraer's aircraft production (in units)
1980-1999

Model	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Civilian																				
Bandeirante	73	67	32	10	23	2	4	7	10	2	8	1	2	0	0	1	1	0	0	0
Xingu	25	12	18	26	2	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0
Brasilia	-	-	-	-	-	6	20	38	46	54	55	35	15	10	7	20	17	8	12	7
ERJ-145	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	32	62	81
ERJ-135	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
Light Aircrafts (Piper/Ipanema)	315	169	117	66	106	112	107	111	81	121	67	51	33	49	43	28	24	24	26	17
Military																				
Xavante	5	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brasilia	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Tucano	0	0	0	26	57	49	35	45	54	10	5	0	1	5	8	18	15	-	6	-
AMX	-	-	-	-	-	-	-	-	-	4	5	8	7	6	1	4	3	5	10	3
TOTAL	418	265	167	128	188	170	167	203	191	203	141	93	54	70	60	66	64	71	115	124

Source: Embraer

[6] The United States market, for instance, represents around 60 per cent of Embraer's sales.

In order to make the ERJ project viable, and given the difficulty of keeping the support of the Brazilian Government during a period of deep structural changes, Embraer, after privatization in 1994, set up a production and strategic model, that would prove to be crucial to its future success. The company formulated a business plan based on achieving financial results through deep organizational and productive restructuring. Embraer started to build a new relationship with clients and suppliers. An action plan was designed in which the mission of the company and a new market strategy were envisaged and production and organizational restructuring was planned. High priority was given to examining the feasibility of the ERJ-145 project.

Embraer's current competitive edge is structured around some basic axes. The first axis consists of outlining a technological strategy aimed at product innovation, coupled with the identification and fulfilling of client/user requirements. In essence, it follows the old technological strategy with some important changes. The company's essential competence lies in the excellence of design and integration of highly complex production systems. The company focuses its activities on adding value as systems' integrator that dominates the different technical phases of the subsystems. It is not important to manufacture them, but to retain the capacity to combine and adapt them according to its project requirements. As an aircraft is made up of over 28,000 parts and components, the capacity to design and specify the product, and to integrate components into several sub-systems in a harmonious way within the fuselage of the aircraft is both complex and difficult. Such a task forms the core of Embraer's strategy. Coupled with marketing and technical services, it is the central element of the company's core competencies. In this respect, Embraer holds the strategic assets that allow it to coordinate the network of the risk partnerships and the global productive chain, thereby strengthening its competitive position.

The second crucial aspect is the so-called "off-load" strategy, which focuses on the globalization of production and the de-verticalization process. Embraer is "trying to dedicate itself progressively more to the noble project activities, such as development, systems engineering and integration, adopting strategies of seeking for partners to manufacture parts and subsystems, as well as assemblies of systems and kits. In this way, its investment in the milling and stamping sectors has been restricted to the partial upgrading of the existent equipment, according to the needs of the production and the absence of suppliers" (Mendonça, 1997). The basic idea behind this model was to spread the high risks associated with such a big project and the pattern of competition in the sector. The model is global in nature, whereby risks, incentives and benefits are shared. Embraer coordinates the whole network that acts in a well-defined, hierarchical structure at three different levels.

At the first level are the risk partners, defined as those that assume financial risks in the projects. At this level there are very few large international firms that participate in the co-design process and add technological value. At the second level are suppliers of components, parts and services ordered by the company. These are almost entirely (98 per cent) located abroad. The relationship of Embraer with these firms is both technological and commercial. It could be characterized as "information networks" through which companies supply such items as equipment, avionics and components according to Embraer's specifications. At this level, there is significant learning-by-interaction, but not such intense innovation as at the first level.

Box I. Embraer's aircraft

The following is a list of Embraer's present commercial aeroplanes:

1. EMB120 – The 30-seater Brasilia: turboprop aeroplane: More than 400 units have been sold. Its main market is the United States. Sales leader in this category for many years, the plane is used by 26 enterprises in 14 countries, and has done more then 3 million-flight hours.
2. ERJ 135: A regional jet for 37 passengers, it is a compact version of ERJ-145. It has the same fuselage (3.5m shorter), wings and wrappings, cockpit (same pilot's licence), turbo-fan motors (Rolls-Royce Allyson), low fuel consumption and noise, common procedures of training and maintenance. In addition, it has a longer range than 2,340km, better performance in higher runways and high temperatures, and low costs of acquisition and operation. Its development entailed a US$100 million investment that must be amortized over a period of 10 years with the sale of 500 aircraft.
3. ERJ140: A new regional jet for 44 passengers, following the "jet family" concept started by ERJ-145. It uses many common features thereby obtaining operational and maintenance benefits, including the same pilot's certification. The development of this aircraft required an investment of about U$45 million.
4. ERJ145: A jet plane with 50 seats, it is intended for the regional market, with 119 units sales confirmed. This product has given the company leadership in the world commuter market. The cost of production was US$350 million.
5. ERJ170: A jet aeroplane with 70 seats. A new platform has been developed as the base for ERJ-190. It is expected to receive certification in the second half of 2002. The estimated sale price is US$22 million for the sale of 400 units.
6. ERJ190-100/200: A jet plane, it is a larger version of the ERJ-170, as a result of the addition of a fuselage section, with stronger engines, a larger wingspan and reinforced landing gear. Two versions are planned, with 98 (ERJ-190 / 100) and 108 (ERJ –200) seats. The process of certification is expected to begin in 2004.
7. Light aeroplanes: Neiva's EMB201 Ipanema, EMB400 Urupema, BEM 710 Minuano, BEM 721 Sertanejo, and BEM Seneca.

Apart from commercial aeroplanes, Embraer also manufactures several military aeroplanes:

1. Tucano is military training aeroplane and world market leader; it stands out because of the ease of flying it and low maintenance costs. More than 640 units have sold.
2. Super Tucano/ ALX is military aeroplane derived from Tucano EMB-312. It represents the new generation of military turbprop aeroplanes developed from the experience acquired with Tucano (BEM-312) in terms of operation and training. This aircraft has a similar cockpit to a fighter, with advanced avionics provided by Elbit from Israel. The ALX fulfils a Brazilian Air Force requirement for a light attack aircraft, to be used in border vigilance. It will also be used for advanced training and operational missions in Amazon, supportingthe SIVAM Project.
3. AMX is a military tactical aeroplane that was conceived and produced by the Aeritalia

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(Box I, concluded)

consortium: Alenia and Embraer. Its most recent version is the AMX-T.
4. The Radar Multimodal Boarded Project developed a "doppler" radar to be part of the AMX aircraft.

Besides these commercial and military aircraft and projects, Embraer is engaged in several other partner ships with major aircraft producers. It supplies flaps for MD11 – McDonnell Douglas (certified by the Douglas quality system), and produces the dorsal fin and the wingtip for Boeing 777 aeroplanes (certified by D1900 – Advanced Quality System for Suppliers of Boeing). It also has a partnership with Sikorsky for the production of S92 helicopters.

Source: Embraer

At the third level are the subcontractors – companies and individuals that receive raw materials and design from Embraer. Relationships at this level have two dimensions: project and engineering services; these are activities involving greater expertise and scientific content rendered by technology companies, and companies that provide milling services, chemical treatment, coating and other production services of lower technological complexity. This group of firms is directly subordinate to Embraer, and most are located in São José dos Campos.

From the operational point of view, several techniques were introduced. In terms of work organization, Embraer introduced methods of functional work flexibility through innovations in operational management of the production processes. Particularly worth mentioning is the setting up of interdisciplinary groups for permanent productivity and quality improvement – *kaizen* – a well-known Japanese work philosophy based on the collective and continuous commitment of workers to improve quality and productivity. Another technique that radically changed the work and production processes was the adoption of the liaison engineering system, a system for linking together several corporate areas, supporting decision-making and eventual resolution of problems of a work team. A specific team is allocated full-time to this activity, and renders support in the assembly or production phase of a product. With the adoption of liaison engineering, a reduction of 50 per cent of the work cycle in the production phase of the EMB-120 and ERJ-145 aircraft was obtained (see table 11).

In 1996, the company invested approximately US$ 8 million in improving production processes in order to increase productivity (see box II)**.** In 1997, investments of some US$ 25 million were made to upgrade equipment and machinery, layout and information systems as well as production control and programming. In the operating area, efficiency gains resulted in reduction of the manufacturing time of the Brasilia, from 14 months to 8 months, and later to 6 months. The restructuring process also resulted in higher productivity, which went from US$ 42,000 per employee in 1994 to US$ 98,000 in 1996, US$ 227,000 in 1998 and US$ 252,000 in 1999. This figure is only 19 per cent below the world average for the sector, which is approximately US$ 300,000 per employee (table 11).

Table 11. Embraer's production indicators

Production indicators	1993	1994	1995	1996	1997	1998	1999
Production cycle (months)							
EMB – 120 - Brasília	-	14	12	8	6	6	5.5
ERJ-145	-	-	-	8	7	5.5	5.5
Production rate (number of aircraft)			-	5.9	4.5	3.6	11
Productivity (sales over number of employees) (US$ '000)	41	42	82	98	166	227	252
Trash/ rework index (%)	-	-	-	2.4	1.2	1.0	0.9
Number of lost days/work hours			132	191	77	72	-
Frequency rate (in millions of work hours)	4.5	5.9	7.1	5.9	4.5	3.8	-

Source: Embraer

Box II. Embraer's main facilities

In 1999 the company's facilities included 106 digitally-controlled machine tools and 11 digitally-controlled milling centres. It also had 4,500 personal computers (486, 586 and Pentium) of which 250 were dedicated to CAD/CAE and workstations, and 150 Intergraph stations with 1 CAE server. In the technology department, the information technology (IT) density is 1/1, that is, one computer for each engineer. For the company as a whole, with a total of 8,000 employees, the density is 1 computer for every 2 employees.

The Stamping Division (GFC) sought to increase the production rate of the ERJ-135 and ERJ-145 aeroplanes in 1999 by implementing a new management system inspired by Japanese production techniques called "lean manufacture". The new system was employed in the milled coverings of the central fuselages II, III and IV of the aircraft, resulting in a reduction of 52 per cent in the assembly cycles and in a 100 per cent of improvement of the total aeroplane kit.

Source: Embraer

Another important institutional innovation in Embraer's strategy was the setting up of a department to monitor critical technologies for the company. Before privatization such activity had been internalized as part of the firm's strategy for training human resources and in the overall activities of its technical departments by constantly reviewing specialized literature and articles and magazines about the sector. The establishment of partnerships and permanent contacts with international suppliers was also important. The company had constantly been working to improve its technological processes, quality and use of new information technologies. This strategy was

formalized by establishing a programme based on a more intensive evaluation of Embraer's external environment through benchmarking by a programme called Brainware. The idea was to monitor the development of new technologies by the main, world-class aircraft manufacturers such as Boeing, McDonnell Douglas, and Sikorsky and by research centres. This resulted in the adoption of new automation technologies for plates and riveting, identification of parts by bar code, and automation of the cabling factory, among others. In 1999 the programme was terminated, since the technological upgrading objective had been successfully reached and the engineering area considered it fully incorporated into Embraer's strategy and production routines. In its regional aircraft segment, vis-à-vis its direct competitor, the company is fully updated and tuned in to best world practices.

Table 12 provides some information regarding the evolution of Embraer's R&D expenditure during the 1990s. The crisis in the early 1990s led to a fall in R&D expenditure from US$ 128 million in 1990 to US$ 24 million in 1992 and US$ 35 million in 1993. With the recovery, R&D expenditure increased again to US$ 141 million in 1998, when the main technology efforts of the EMB-70 family peaked. It is also worth pointing out that expenditure in IT equipment also increased significantly in the second half of the 1990s, as part of the modernization strategy. According to Embraer, about 50 per cent of technology expenditure is directed to internal R&D, 30 per cent to industrial design, 15 per cent to new product commercialization, and 5 per cent to capital expenditure in plants, machinery, software and other equipment associated with new products or processes.

Table 12. Embraer's technology expenditures, 1990 – 1999
(US$ million)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
R&D/sales (%)	12	7	4	7	17	17	14	5	5	4
R&D total	128	48	24	35	55	92	96	69	141	68
R&D civil	-	-	-	-	-	69	84	44	56	20
R&D military	-	-	-	-	-	23	12	25	85	48
IT equipment	0.9	0.5	0.2	1.1	1.0	1.5	3.2	5.0	14.0	6.0

Source: Embraer

3. The strategy in action: the ERJ-145 and ERJ-170/190

Together, the restructuring and the partnerships strategy were responsible for creating a new corporate logic and dynamic and a competitive business architecture. They generated both pressure points and synergies, particularly in the area of production, and had a deep impact as far as cost reduction was concerned. However, the ERJ-145 programme and the ERJ-170/190 family, although having several similar concepts, represent two different approaches. The first may be characterized as having a greater focus on costs, with the risk partners being considered

by Embraer more as suppliers of components than real partners. The ERJ-170/190 programme was developed in a different context, with value aggregation and technology, rather than cost, being considered as essential for the feasibility of the project. The two cases are summarized in boxes III and IV.

The coordination and administration of the contracts and the supply chain in the business organization model for the ERJ-145 programme was an invaluable learning process for Embraer. As mentioned above, Embraer had a very positive experience with international corporations. The lessons learned from the AMX cooperation project, promoted in 1979 by the Brazilian and Italian Governments, were fundamental for the managerial development and harmonization of the dynamics of the business relationships of the ERJ-145 programme. In this sense it could be argued that this successful experience was also built upon earlier strategies developed when the whole aeronautical programme was government-controlled.

To synchronize the progress of the several participants in the ERJ-145 programme, a steering group was established, which held periodic meetings with the representatives of each partner, potential customers and representatives of the pilots' associations. For Embraer, perhaps the single most important lesson from this project was in the management of contracts between companies, rather than the acquisition of new technologies. In fact the only technology it acquired for the ERJ-145 was a leading-edge de-icing system. Embraer developed all the other important technologies, either alone or jointly with the risk partners, from the older turboprop technologies of the Brasilia and Bandeirantes projects. Technologies developed and accumulated over the years by Embraer were fundamental for the new project, to the point that some commentators have argued that the new jet aircraft (the ERJ-145) was basically the same old Brasilia (a turboprop aircraft) with jet engines. An associated benefit of the project was a reduction in production costs through the subcontracting strategy. By radically vertically disintegrating the production process, Embraer created the conditions that made it possible to reduce the final price of the aircraft. This simple approach was probably responsible for the most important competitive weapons of the ERJ-145: its low price, and ease and low costs of maintenance. In short, even though the strategy that guided that partnership programme was clearly a focus on cost reduction and financial engineering, the success of the enterprise was possible because the ERJ-145 project was designed using updated technologies from the older turboprop projects.

Box III. The ERJ-145 programme

The ERJ-145 programme was designed in 1989, while the company was still State-owned. However, it only became financially feasible after it gained business flexibility and agility following privatization of the company and the creation of risk partnerships. It is important to point out that Embraer was able to attract partners on the world market who believed in, and invested in the ERJ-145 project because the company had design and technology capabilities that other competitors did not. Certainly, if the company had not enjoyed a strategic position on the market, as a generator of the technology, the possibilities for securing partnerships would not have been so promising. The ERJ-145 programme, with four companies (Gamesa of Spain, ENAer of Chile, SONACA of Belgium, and C&D Interiors of the United States) as risk partners, was based on the idea of spreading risk among partners and on the commitment of each participant to develop a sub-system of the product. This programme reflects the strategy outlined above; that is, a new standard of corporate organization that was better integrated and flexible was developed and articulated in the form of core networks of development, learning and technological innovation. This works for the financing of projects as well as partially diluting the risk of market uncertainties. Besides learning the coordination of business networks, other important capabilities were acquired including the management of complex contracts, time- frames and flows of parts and components and the controlling of work cycles and product quality, all of which helped to radically changing Embraer's corporate habits. Years ago this type of international project and aircraft production would have been unusual and not viewed favourably on the part of the Brazilian Government which was more concerned with security implications, especially in industrial secrecy. Today, due to escalating costs and the long R&D cycles inherent in the entire conception and production of a new aircraft, as well as the uncertainties and the long time-frame for a return on investment, these corporate and institutional arrangements have become the rule for those who wish to survive in this arena. In the technological field, the programme did not present a problem and Embraer had all the necessary conditions to manufacture the aircraft at its facilities.

The main obstacle to viability was Embraer's lack of credit. The firm was in debt and internally disorganized. The estimated cost for the development of the ERJ-145 programme was US$ 300 million. The risk partnerships established in 1992/93 with suppliers gave a new impetus to the programme. In 1995, with Embraer already privatized and under control of a new administration, the programme was taken up again and given high priority. The solution was the identification of international companies interested in investing in the programme and in assuming responsibility for the production of parts of the aeroplane with the acquisition of aeronautical technology from Embraer, and in return they would share in the profits from sales of the aircraft. Of the total anticipated investments, Embraer put up approximately US$ 140 million for the development of the aeroplane, assuming 60 per cent of the cost, while the risk partners and suppliers bore the remaining US$ 100 million in costs.

In Brazil, Embraer's big partner was BNDES, which financed US$ 100 million. Between 1995 and 1997, the total investment in the programme for technological development and productivity was US$ 287 million with another US$ 120 million in 1998. The Spanish company Gamesa was responsible for the production of the wings, engine nacelles, fairings of the wing/fuselage junction and the doors of the main landing gear. Sonaca, headquartered in Belgium, committed itself to the production of the luggage, service and main doors located in the fuselage, a front and a rear section of the fuselage and the two motor pylons. The Chilean company ENAer produced the horizontal stabilizers and rudder controls. The interior of the passenger cabin and luggage compartment was developed and manufactured by C&D Interiors – one of the largest

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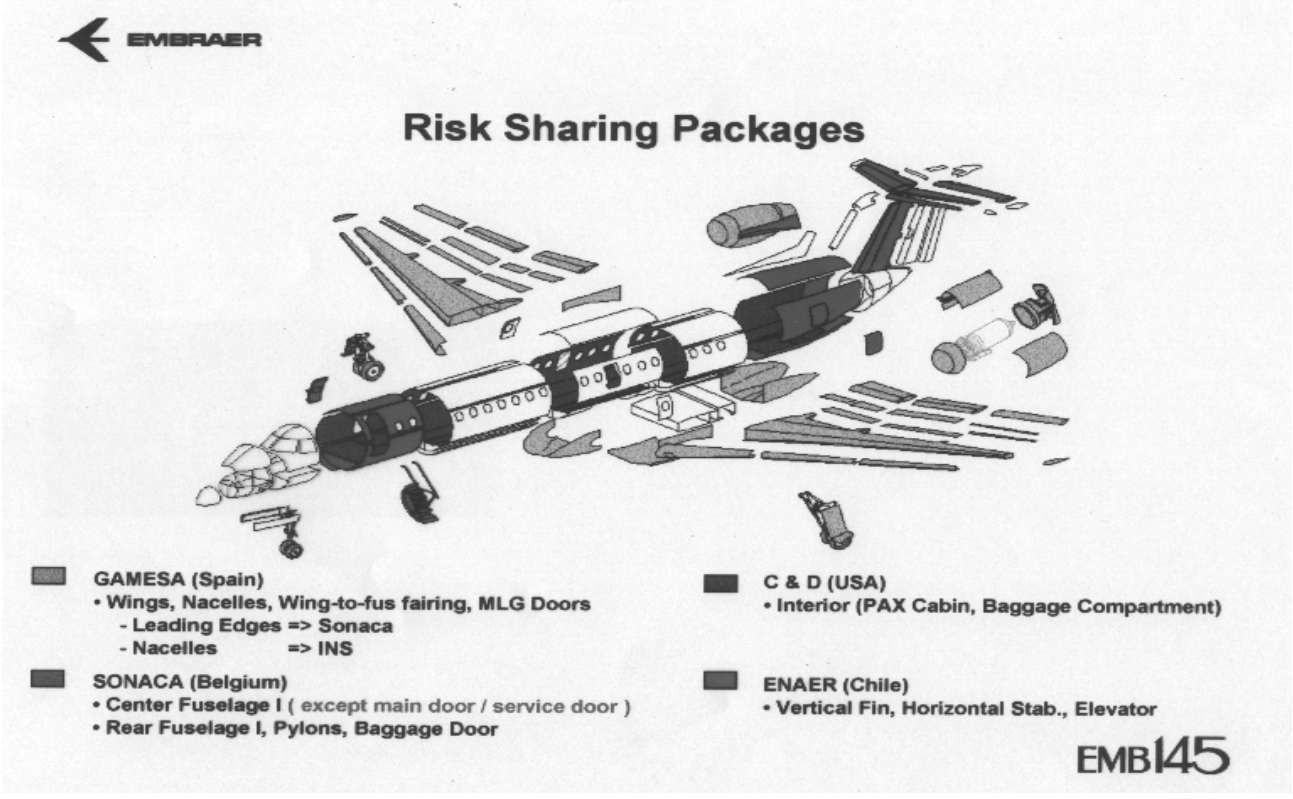
(Box III, concluded)

companies of the world specializing in this area. The programme has 68 suppliers of components, besides employing 2,300 people in outsourced partners and 350 people directly at Embraer. Figure 1 below provides a more detailed visual of the risk partnership programme. It is worth mentioning that the risk partners were selected based on their previous associations with Embraer. They had been important suppliers or associated firms during the old turboprop projects and decided to accept the risk of a project that had a yet unknown future. Embraer had to take this line because it did not have the financial muscle to proceed alone, and was sure that from the technical point of view the partnerships would be successful.

Source: Embraer

Figure 1 – Division of Labour between Embraer and its Risk Partners for the ERJ-145/140/135



Source: Embraer

The development programme for the ERJ-170/190 project was conceived using a different approach to that of the ERJ-145 programme. The development of the new family of regional jets required an investment of about US$ 850 million. To secure this magnitude of funding, it was necessary to seek a larger participation of companies and international financial institutions capable of financing the whole project. From the technological point of view, given the tight timetable Embraer had to select partner companies and abandon any idea of fostering local capabilities, at least for the most sophisticated technologies. The selected companies would also participate in the development of process engineering and tooling production of the aeroplane's components. The strategy of seeking out multinational partners aimed at securing added technological value to meet three high level requirements: technical training, supply capability and integration of "technological packages", in addition to assuring a sound financial and investment structure.

The innovation strategy also involved a process of institutional and organizational updating. It consisted, for instance, of the upgrading of the electronic mock-up. In the ERJ-145 project, the principles of *concurrent engineering* were applied in order to eliminate the need for modifications originating from production and maintenance problems. Applying concurrent engineering with real time connection via CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) during the entire development process involved several project teams, and manufacturing and technical assistance from Embraer and its main suppliers. The design of each component and part, totalling approximately 19,518 different items, was facilitated by the use of a new technology based on CAD already used in the development of the Brasilia.

The electronic mock-up not only made it possible for the ERJ-145 to be totally designed by computer, but also practically eliminated one of the most traditional stages of an aircraft's development. By generating three-dimensional images of each part and component of the ERJ-145 in real time and integrating them in a single database, the electronic mock-up allowed a meticulous analysis of each part of the aircraft and its relation with the other components connected to it. The use of the electronic mock-up eliminated the traditional mock-up work (a full-scale study model manufactured in wood). This resulted in a 50 per cent reduction of personnel (from 75 to 38 engineers) and a saving of approximately 93,000 man-hours (or US$ 3 million).

Another fundamental improvement was the flight simulator of the EMB-170, in which a database containing the aerodynamic characteristics of ERJ-145 was introduced. Through this artifice the pilots "flew" the ERJ-145 before it even existed, collecting information and correcting flight imperfections. The simulation of the airflow around the aeroplane, made possible by CFD (Computerized Fluid Dynamics) technology, was fundamental in the development of a new "cleaner" wing, with a supercritical profile developed by Embraer. The complete development of the jet involved two million working hours or approximately four years.

Box IV. The ERJ-170/190 programme

The first major difference of this programme as compared to the ERJ 145 is the greater integration and sophistication of strategic partnerships. The project of the aircraft, for instance, was co-designed with the partner companies. Embraer has a 45% share in the design and is responsible for the integration of all systems, aircraft structure and final assembly technique. The group of risk partners integrating the programme of the new family of regional jets for 70, 98 and 108 passengers, designated the ERJ-170, ERJ-190-100 and ERJ 190-200, were selected based on the analysis of 85 potential partners; of which 58 were pre-qualified and 16 were chosen.

The risk partnership idea got more complex with the new programme. General Electric (GE), the largest participant is responsible for the supply of the turbines. The engines represent about 20% of the sales price of the aircraft, estimated to be around US$ 22 million in the case of ERJ-170 and US$ 27 million for the ERJ-190. GE also holds 99.6% of Celma, an Embraer supplier of motors, accessories and parts, located in Petrópolis in the state of Rio de Janeiro. According to the specifications, the new aircraft is faster than the ERJ-145, cruising at Mach 0.80, and meeting the challenge of low operating costs in relation to competitors. Other important partnership is with the US Honeywell (taken over by GE for US$ 48 billion in 2000), who supplies most avionics. Gamesa, which integrated the previous programme, develops and supplies the *empennages* and the rear fuselage. Hamilton Sundstrand is responsible for the fuselage rear cone, among others. Figure 2 provides a visualization of the risk partnerships for the ERJ-170 family. There has been also an important progress related to the reduction of the number of suppliers, with the increase of the number of parts and components for each one. The aerospace division of Kawasaki Heavy Industries, from Japan, is also among one of the ten companies chosen as risk partner. Kawasaki will invest US$ 100 million in the development of the central part of the wing, control surfaces and pylons (motor support structures). And, finally, EDE, the Equipment Division of Embraer, established a joint venture with Liebherr (Germany) for the supply of the landing gear.

Several elements are crucial to the understanding of this programme. The first is that a rigorous and strategic selection of the new partners, emphasizing capacities to develop new technologies and investment. The second point to be emphasized is the decision by Embraer, after 20 years (since the Brasilia programme), to internalize the production of the aircraft wing. This task, in the ERJ-145 programme, was the responsibility of the Spanish company Gamesa and Embraer considered it to be too critical to the company to be left to other partners. Finally, there was a change in the system of innovation and development of the project engineering, towards a system of more integrated routines and co-ordination among the partners. From the operational point of view, the ERJ-170/190 programme was organized in three phases (which can be visualized in Chart 3). Phase 1 - "Initial Definitions" – involved the concept and detailing of the aircraft design. This was done before the choice of risk partners. A business plan was prepared focusing on market requirements and product detailing. Cost planning, analysis of the life cycle; investment, analysis of the risk and return on the investment were part of this phase. In addition there was a specific market identification study with a methodology prepared by Embraer.

The second phase - "Joint Definitions" - was characterized by the division of the aircraft in several sections and the division of the work among the companies; it was followed by the joint definition of the aircraft parameters among the partners and Embraer. The innovation made during this phase was the internationalization of R&D routines that were developed through the use of a *co-operative engineering*, i.e. the setting up of a network of R&D between plants and laboratories of the several international partners centralized and co-ordinated by Embraer in Brazil. This institutional arrangement involved the establishment of decentralized multi-disciplinary teams, in a

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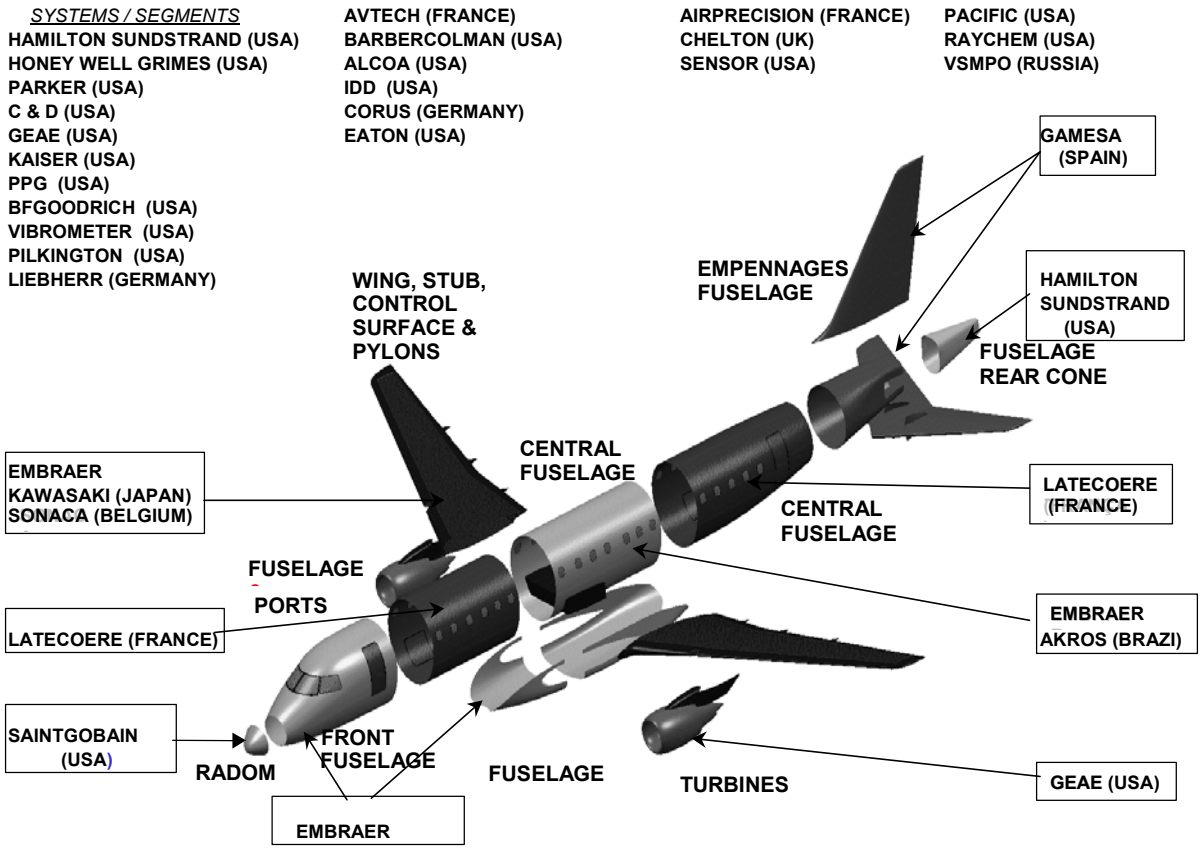
(Box IV, concluded)
type of matrix structure. Innovation teams organized it across the entire company, for the joint development of aeroplane components with the partners. These procedures allowed the integrated development of the product, since all decisions taken were made by specialists from company partners and who therefore, had the decision-making authority. About 600 full-time engineers were assigned to the programme, with 300 specialists from Embraer and 300 specialists of the other international partners, from Japan, Spain and the U.S., among others, who worked intensely and "in-house" at the Embraer headquarters in Brazil. The engineering work and project was performed in the Embraer advanced data-processing centre that provided a fully integrated project atmosphere. The co-design strategy permitted savings 18 months in the development of the aircraft (36 instead of 54 months), with substantial gains in quality. With the implementation of web systems and EDI - Electronic Data Interchange, it was possible to call on-line the network of partner firms in the electronic mock-up and the ERJ170/190 database that were centralized in the Embraer IT structure. The general design modifications made by the partners and suppliers were sent electronically to Embraer, where they were checked and validated for later updating of the mock-up and database. The final phase - "Detailed Design and Certification" – is where the final definition of the aircraft is made. The engineers and technicians of the partner companies return to their home countries to finish the detailing phase and require the certification of the aircraft in different markets.

Source: Embraer

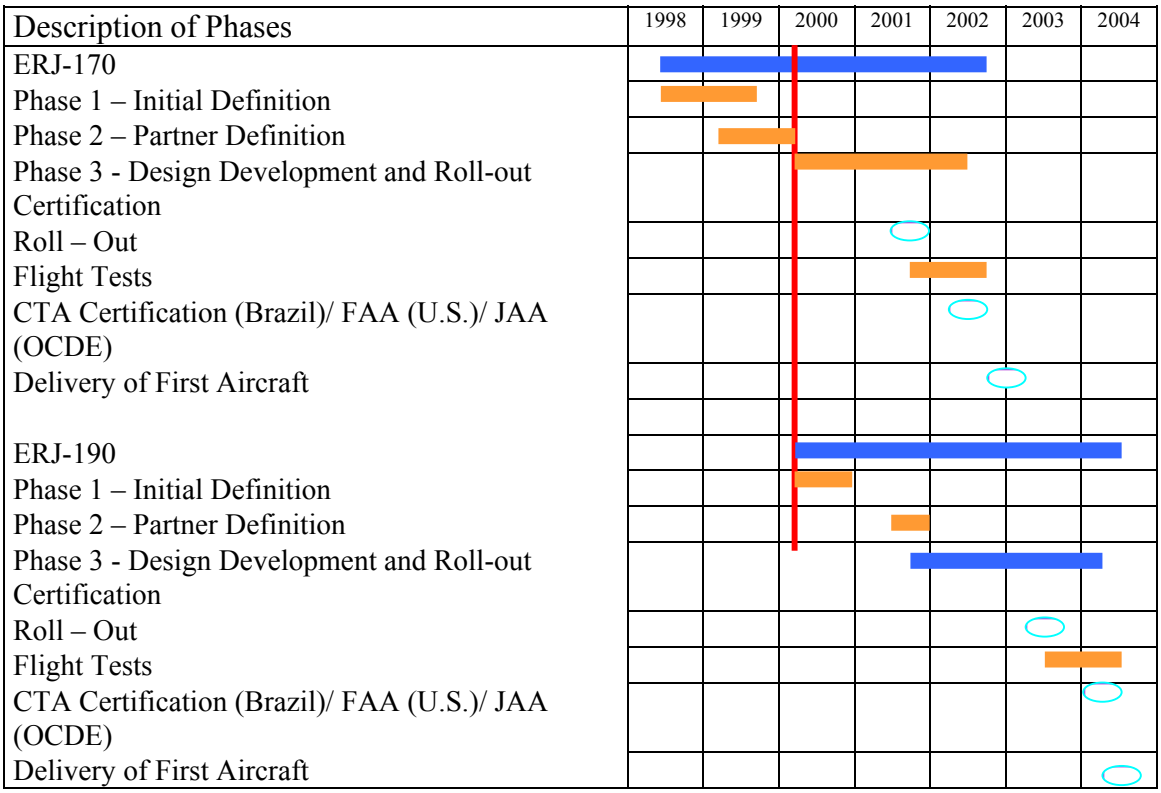
Figure 2 Division of Labour between Embraer and its Risk Partners for the ERJ-170/190



Source: UNCTAD based on Embraer.

Another important improvement was in the transition of the electronic mock-up to digital mock-up and in the project software, migrating from the Intergraph used in the ERJ-145 programme for Catia software developed by the French company Dassault (employed in the ALX and Sikorsky programmes), to the Virtual Reality Centre (VRC). The knowledge acquired in the use of Catia was fundamental for the implantation of the VRC.[7] Its use in the development of the new family of ERJ-170 and ERJ-190 regional jets enabled a more effective decision-making process, with early identification of problems, mistakes and design flaws. It enabled a reduction of 50 per cent in the time of the activity cycle (from completion of the design of the aircraft to certification) and the time-to-market. The development time frame of the ERJ-170/190 was cut to 38 months instead of the 60 months taken by the ERJ-145 programme, representing a cost and time saving for manufacturing of between 5 and 10 per cent.[8]

Chart 3. Time schedule of the development stages of the ERJ-170/190



Note: CTA (Technological Airspace Centre, Brazil), FAA (Federal Aviation Administration, United States), JAA (Joint Aviation Authority – European equivalent to FAA), OECD (Organisation for Economic Co-operation and Development).

Source: Embraer

[7] Embraer built the VRC in partnership with SGI Silicon Graphics Inc., which represented the biggest investment of the company in IT, at a cost of US$ 2.6 million. The Centre began operation on 7 February 2000.

[8] Until end-2001, besides Embraer, only Petrobras in the petrochemical sector and GM (General Motors) in the automotive sector operated with such a system in Brazil, and only partially.

One of the main advantages to the company in assembling the Virtual Reality Centre was that it expedited the development process of aircraft using the same technology as the biggest aerospace industries in the world. Thus teams involved in projects will no longer be required to build replicas of each model developed, in real size or in scale, for tests – a significant saving of project time and costs. This system allows the designer to accomplish a "virtual tour" in each section of the aircraft, perform tests and model structures, for example. CRV technology can be applied in several areas such as in design and manufacture, human model simulation, marketing (some sales were confirmed after the buyers made the virtual tour within the aeroplane), design review, hangar manufacture, kinematics, ergonomics and corporate presentation, among others. This system also allows the certification authorities to better evaluate the aircraft as it is being built.

All these changes had a significant impact on the labour force. Figure 3 below shows the evolution of Embraer's workforce over the 1990s, particularly the significant reduction in the number of employees during the crisis period. With recovery in the second half of the 1990s, the employment level increased again. It is important to highlight what happened with employment of more qualified personnel. During the restructuring phase, although the Technology and Engineering Department, considered the strategic nucleus of the company, was spared from outsourcing, many engineers and highly qualified technicians were laid off. Obviously, with their departure the knowledge accumulated over the years was lost. Due to the high training costs and recycling time it takes for one (aeronautical) engineer to be able to act in other areas, when the sector boomed again in the late 1990s it was not easy to re-employ them.[9]

However, with the recent recovery of the sector many engineers and technicians have returned to Embraer. On the other hand, many services such as cleaning, catering, security, certain areas of information technology (IT), pilot and other employee training, transportation and some services associated with the design all started to be outsourced. The outsourcing of indirect activities resulted in savings of approximately US$ 80 million. In the first semester of 2000, Embraer had 9,000 direct employees. Of these, 1,500 (16.7 per cent of the total) were engineers, and, according to estimates of the local metal workers' union, outsourced activities accounted for 4,000 jobs.

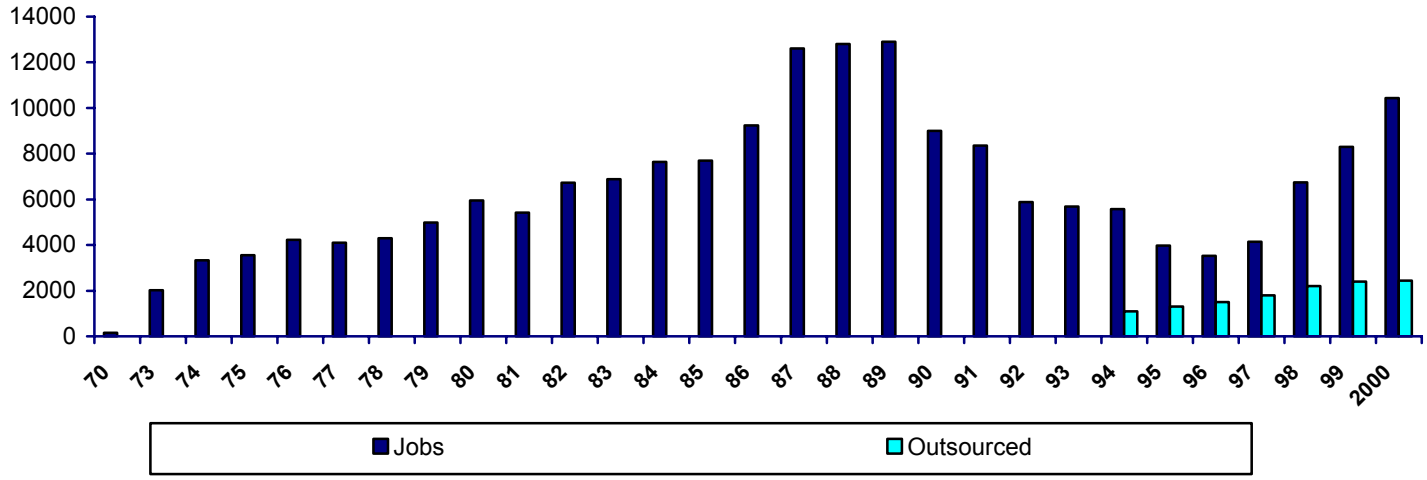
It is expected that investments in the new family of regional jets will raise sales to US$ 4 billion over the next four years, making Embraer is one of the few Brazilian brands to enjoy prestige and a dynamic participation in the medium- and high-tech world market. It plans to invest in a new plant, to be located in the city of Gavião Peixoto, in the area of Araraquara, where military aircraft production lines, new versions of jets for corporate use and the construction of a test runway for Embraer aeroplanes will be located. The investment is expected to generate 3,000 new jobs. Two equipment and component suppliers, Tamesa and CMB, have confirmed their installation of two new plants near the new Embraer factory. Close proximity to one university (Unesp) and to the engineering school of another (São Carlos Federal University) was taken into

[9] Also, given the crisis that affected the entire Brazilian economy in the 1990s and the few R&D activities in most Brazilian industries, many engineers had great difficulty in finding a new technical job. Indeed, there are several reported cases of qualified engineers from Embraer changing their occupation and downgrading their activities (working as salespersons, for instance). Some managed to be hired by other companies, some created their own businesses and others were recruited by foreign aerospace firms and migrated.

consideration for the choice of location, as was the availability of local fibre optic infrastructure, and fiscal incentives.

The final net results of these changes in the aircraft innovation system are difficult to measure. However, it is fair to say that it has probably had mixed results. With the prospect of production, growth and development of new products, it is estimated that 4,000 new jobs (both direct and indirect) will have been created during the period 2000–2002.

Figure 3. Embraer: Total employment, 1970-2000



Source: Embraer

CHAPTER V

CREATING LOCAL SYSTEMS OF INNOVATION FOR AIRCRAFT PRODUCTION IN SÃO JOSÉ DOS CAMPOS

This chapter discusses the role – real and potential – of the local innovation system of São José dos Campos in Embraer's strategy. As a result of the high growth of the aircraft sector, the Vale do Paraiba region (composed of the towns of Caraguatatuba, Cruzeiro, Guaratinguetá, Taubaté and São José dos Campos) accounted for more than 15 per cent of the country's exports in 1999. This region has been named "The Technology Valley" because it has the largest concentration of high-tech industries in Brazil.

The São José dos Campos region hosts several plants belonging to local and multinational firms that are of strategic importance in global and local production chains. These firms include: Embraer and Avibrás in the aerospace business, Volkswagen, Ford and General Motors in the auto industry, Ericsson in telecommunications, and the petrochemical plant of Petrobrás. In less than 40 years a local production and innovation system geared towards the production of aircraft has been developed. This chapter discusses some aspects of this system, in particular local institutions that provide R&D infrastructure, firms that supply goods and services to Embraer and recent institutional arrangements being introduced in the region that are geared towards increasing local capabilities.

1. Scientific and technological infrastructure

The successful creation of an aircraft cluster in the São José dos Campos region is largely the result of the Government's efforts to create a robust scientific and educational infrastructure aimed at meeting the high-skills requirements of the aircraft industry. The Technological Airspace Centre (CTA) and National Institute of Space Research (INPE) are the leading institutions in this area. The CTA, which is a branch of the Department of Research and Development (DRD) of the Ministry of Aeronautics, consists of four institutes: the Aeronautic Technology Institute (ITA), which is a teaching organization; the Aeronautic and Space Institute (IAE); the Institute of Advanced Studies (IEA); and the Institute of Industrial Liaison (IFI). In 2000, CTA employed approximately 4,000 researchers to work on development projects for the aeronautic, space and defence systems in the areas of advanced materials, physics, chemistry, electronics and computer sciences. Computer simulations, a wind tunnel, and soil and flight tests complement basic research. As most research is linked with industry, CTA has acquired capabilities in metrology, quality, standardization, reliability and R&D management. INPE is designed to conduct research in space and atmospheric sciences and space applications. It offers graduate and post-graduate programmes and has research programmes for satellites and their sub-systems, including tests, tracking and control integration.[10]

[10] The Technological Airspace Centre (CTA) and National Institute of Space Research (INPE) are leading educational institutes located in São José dos Campos, offering graduate and post-graduate courses in different areas of the aerospace sector to 600 and 130 students respectively. ITA has post-graduate programmes in aeronautical and

The region also hosts other important training institutions, such as a local branch of SENAI (National Industrial Learning Service), which is part of the National Confederation of Industry (CNI) and is geared towards providing training for workers. A partnership agreement between SENAI and Embraer provides training to 40 students per semester until 2010. The objectives of this youth apprenticeship programme are to train young relatives of Embraer employees in the fields of mechanics and electronics in order for them eventually to be employed by Embraer. In return, Embraer will build a modern telematics laboratory at the SENAI branch in São José dos Campos.

2. Locally subcontracted small and medium-sized enterprises

As mentioned earlier, Embraer designs and develops aircraft projects and integrates and assembles systems, structures, the fuselage and components. It was also pointed out that the competitive strategy of Embraer is based on coordinating a global network of risk partners, world suppliers and local subcontractors.

Apart from the risk partners already discussed, Embraer has about 450 to 500 supplier companies for the ERJ-145 programme. Most of first-level suppliers are located abroad. Up to 2001, about 95 per cent of the suppliers were located abroad: 73 per cent in the United States, 25 per cent in Europe and the remaining 2 per cent in other countries. Of 43 first-level suppliers, there is only one Brazilian firm, EDE that produces the main landing gear (table 13).

In the ERJ-170/190 programme the total number of suppliers was reduced to 40 companies, most of which are located abroad (95 per cent). As Embraer designs new forms of relationship with suppliers, United States firms are losing their share (53 per cent), while Japanese firms are now participating (8 per cent) and European firms (27 per cent) and companies of other countries (8 per cent) are gaining relative importance (table 14).

mechanical engineering, electronics and computer science, airspace infrastructure, industrial engineering and organization, and physics. Since its inception in 1961, some 830 students have graduated with master degrees, 110 with doctoral degrees, and 120 specialists. INPE offers post-graduate courses in meteorology, remote sensoring, space engineering and technology, applied computing, space geophysics and astrophysics. It has produced 690 graduates with a master degree and 150 with PhDs since it was set up in 1968. On a smaller scale, human resources for the cluster have also been provided by the Mechanical Engineering School of University of São Paulo - São Carlos (USP), the University Vale do Paraiba (UNIVAP) and the Federal University of Minas Gerais, which also offers graduate courses for engineers, specializing in aeronautics.

Table 13. First-level suppliers for the ERJ-145/140/135 programme

Class and suppliers (Distribution %)	Components supplied	Country
Hardware (4%)		
Electrical		
E.G. & G. Rotron	Electronic compartment and cooling fans	United States
Matrix	Connectors	United States
Mechanical products	Circuit breakers	United States
Raychen	Wires and cables	United States
Vickers	Hydraulic pumps	United States
Eaton-MSC	Buttons	United States
ECE	Contact points and fuses	United States
ABG Semca	Pressurization equipment	France
AIIied Signal	GPWS/wind shear detector, pneumatic start-up and CVR/FDR	United States
Mechanical		
B.F.Goodrich	Wheels and brakes	United States
Goodyear	Tires	United States
EDE	Main landing gear	Brazil
Liebherr	Auxiliary landing gear and flap control	Germany
Mason	Aerodynamic brake stick	United States
Aviac	Stick pusher. pedal adjustment actuator and fire shut-off valve	France
Crane. Hydro Aire	Brake controls	United States
Raw material (2%)		
Alcoa	Aeronautical aluminium	United States
Equipment (60%)		
Allison	Motor AE 3007	United States
Lord	Motor front	United States
Eros	Crew oxygen	France
Rosemount	Ice detector and stall protection	United States
Sextant	Altimeter and speed indicator	France
Sicma	Pilots Seats	France
Sierracin	Windshield and bad weather window	United States
Struthers Dunn	Relay	United States
Systron Donner	Fire detector	United States
Technofan	Fan	France
Vibro-Meeter	Central maintenance computer and motor vibration monitoring	Switzerland
Parker Hannifin	Hydraulic, fuel and flight command systems	United States
Eldec	Proximity sensor	United States
Grimes	Warning units, alarms and illumination	United States
Hamilton Standard	Air conditioning and pneumatic system	United States
Honeywell	Avionics	United States
Jet Electronic	Altitude indicator and emergency battery	United States
Lucas Aerospace	Power generation	United States
Marathon Power Technologies	Batteries	United States
Pacific Scientific	Fire extinguisher	United States
Avtech	Communication with passengers	United States
Metallic structures (34%)		
Gamesa	Wings, engine nacelles, wing fairings/fuselage junction and main landing gear doors	Spain
Enaer	Horizontal and vertical empennage	Chile
Sonaca	Luggage compartment service and main doors, front section and pylons	Belgium
Sundstrand/ Labinal	APU, APIC	United States/France
Norton	Radome	United States

Source: Estimates supplied by Embraer.

Roughly, the relative weight of inputs for the production of Embraer's aircraft is as follows: 60 per cent equipment (e.g. engines, avionics and air-conditioned systems), 34 per cent metallic structures (subsets, wings and careenage), 4 per cent electric components (wires, cables and systems) and mechanic systems (e.g. brakes and wheels) and 2 per cent basic inputs (e.g. aluminium, titanium, kevlar and carbon fibre). Risk partners are responsible for 36 per cent of the total (in value terms), international suppliers for 57 per cent and national suppliers, mostly small and medium-sized enterprises (SMEs), for 7 per cent. Considering the final cost of the aeroplane, the local content is approximately 4 per cent, distributed in the following way: 2 per cent consists of engineering services, usinage and manufacture of composite materials by local SME and 38 per cent is the value added by Embraer (e.g. wages, product development and depreciation). [11]

Perhaps of greater significance is the fact that the growing importance of Embraer and the way its strategy has been designed are attracting several firms to locations near Embraer's manufacturing plants. Embraer already buys several important services (e.g. engineering, software, management, thermal treatment), avionics and other industrial inputs from its local suppliers. Inter-firm relationships established in this region present different levels of integration and commercial and technological transaction flows, but with a high degree of vertical integration and coordination. Today, the local aircraft industrial cluster comprises approximately 40 SMEs organized around Embraer.

Most local suppliers are locally-owned and were set up by Embraer's former employees and fostered by Embraer itself. These local SMEs (e.g. Cemic, Akros, Digicon, Elebra, Eleb, ETA, Mectron, Neuron-Eletrônica, Fibra Forte, Aeroserv, Qualitas, N&N, Tectlecom and Alltec) depend on local R&D centres and participate in the aircraft production chain through a direct subcontracting system with Embraer. There are also some other local suppliers that participate in the production chain through subcontracting with other risk partners. Table 15 shows some examples of firms in the São José dos Campos area, in Campinas (70 kms. from São José) and Porto Alegre in the south of Brazil, that are subcontracted by Embraer and its risk partners to provide high quality technical services and manufactured goods.

There are also some important firms that are part of the productive chain, supplying parts, component and technical services, that are located in other Brazilian regions, such as GE/Celma (Petrópolis – RJ), Aeronaut and Aeroeletrônica (Porto Alegre – Rio Grande do Sul), Rolls Royce (São Bernardo do Campo-SP), and NEIVA which belongs to Embraer (Botucatu – SP). All this important network of highly competitive firms has originated from policy design rather than from market forces.

[11] The definition of the local content index follows BNDES criteria. Relative shares were calculated taking as the base the final price of an aeroplane in 2000. Financial information was taken from Arthur Andersen's accounting reports for 2000 and 1999. For details see Bernardes (2000).

Table 14. First-level suppliers of the ERJ-170/190 programme

Category and suppliers (Distribution %)	Component	Country
Hardware (4%)		
Electric		
BFGoodrich	Smart probe	United States
BFGoodrich	Stick shaker	United States
BFGoodrich	TAT	United States
BFGoodrich	Windshield wiper	United States
Hamilton Sundstrand	Electric system	United States
Raychem	Wires & cables	United States
Eaton	Push buttons	United States
Mechanical		
Liebherr	Landing gear	Germany
Barber Colman	Windshield heater	United States
Parker	Flight controls	United States
Pacific Scientific	Fire protection system	United States
GEAE - GE Aerospace	Power plant (engine & nacelles)	United States
Air Industries	Mechanical hardware	United States
AHG	Mechanical hardware	France
Fairchild	Mechanical hardware	United States
Pentacon	Mechanical hardware	United States
Textron	Mechanical hardware	United States
Equipment (60%)		
Parker	Fuel system	United States
Hamilton Sundstrand	Air management system	United States
Chelton	Static discharger	United Kingdom
AVTECH	Passenger address system	France
Honeywell	Avionics	United States
Chelton	Antennas VHF	United Kingdom
Sensor	Antennas VOR/ILS	United States
Allied Signal	EGPWS	United States
Allied Signal	SSCVR / FDR	United States
Air Precision	Clock	France
Parker Hydraulics	Hydraulic systems	United States
Vibrometer	EVM	Switzerland
Hexcel	Composite material	United States
Pilkington Aerospace	Pax window transparencies	United States
PPG Industries, Inc.	Windshield transparencies	United States
Honeywell (Grimes)	External and cockpit lighting	United States
IDD	Lighted acrylic panelling	United States

Table 14. First-level suppliers of the ERJ-170/190 programme (continued)

Category and Suppliers (Distribution %)	Component	Country
Raw materials (2%)		
Alcoa Mill Products	Aluminium plates & sheets	United States
Corus	Aluminium plates & CTS	Germany
VSMPO	Titanium plates & sheets	Russian Federation
Alexco	Aluminium extruded shapes	United States
Pechiney Aviation	Aluminium extruded shapes	France
Alcoa Forged Products	Aluminium forged parts	United States
Otto Fuchs	Aluminium forged parts	Germany
Neuvant	Aluminium forged parts	United States
Structures (34%)		
Kawasaki	Wing stub	Japan
Kawasaki	Fixed leading edge	Japan
Kawasaki	Fixed trailing edge	Japan
Kawasaki	Pylon	Japan
Kawasaki	Control surfaces	Japan
Latecoere	Centre fuselage I	France
Latecoere	Centre fuselage III	France
Latecoere	Doors	France
C&D	Interior	United States
Sicma	Pilot / co-pilot seats	France
Gamesa	Rear fuselage	Spain
Gamesa	Horizontal empennage	Spain
Gamesa	Vertical empennage	Spain
Akaer	CFII / wing fuselage fairing project	Brazil
Kaiser	Throttle / autothrottle	United States
Sonaca	Centre fuselage II	Belgium
Sonaca	Slats	Belgium
NMF	Wing skins	United States
Saint Gobain	Radome	United States
Hamilton Sundstrand	APU/tail cone	United States
Tools and Manufacturing Services		
Dynamic Solutions	Tool project	Brazil
Matrinor S.L.	Fairing tools	Spain
(Several Companies)	Tools Manufacturing	Brazil

Source: Estimates supplied by Embraer

Table 15. Local firms subcontracted by Embraer and its risk partners

Firms	Region	Subcontractors	Type of Activities Subcontracted
Aeroserv	RSJC	➢ Embraer ➢ Gamesa ➢ Sonaca	➢ Assembling and structural services ➢ Aircraft configuration services ➢ Aircraft configuration services
Akros	RSJC	➢ Embraer ➢ Latecoere ➢ Sonaca	➢ Project engineering services ➢ Project engineering services ➢ Project engineering services
Aeromot	Porto Alegre RGS-	➢ Cyclone	➢ Complex technologies and structural assembling in metallic and composites materials, superficial and thermal treatment.
Dynamics Solutions Engenharia	Campinas	➢ Embraer ➢ Hamilton Sundstrand ➢ Latecoere ➢ Gamesa	➢ Tool engineering ➢ Technical support ➢ Engineering services ➢ Engineering services and technical support
Serco Engenharia	RSJC	➢ Embraer ➢ Latecoere ➢ Sobraer	➢ Engineering services ➢ Engineering services ➢ Engineering services

RSJC = Region of São José dos Campos
Source: Bernardes (2000)

3. Support institutions

Thus, for decades support institutions have played a key role in the creation of Embraer, as well as in the development of the São José dos Campos aircraft innovation system. These have included several municipal, state and federal agencies, especially those at the Ministry of Aeronautics, the Brazilian Socio-economic Development Bank and FINEP, the agency for technological development of the Ministry of Science and Technology.

What follows is a description of the initiatives introduced in the 1990s, when, in the absence of federal programmes, most of the institutional support involved basically municipal and state as well as private agencies. In 1992, the Pólo Vale Foundation was set up with the objective of fostering the setting up of technology-intensive SMEs. It had the support of the Commercial and Industrial Association of São José dos Campos (ACI) in partnership with the city government of São José dos Campos, and the government-sponsored service to support SMEs, Sebrae and Univap (the University of Vale do Paraíba). Its institutional mission was to create and manage a technological cluster in the area through a programme for incubating technology companies. In 1993, the Pólo Vale Foundation signed a protocol of intent with the Ministry of Science and Technology (MCT) whereby it would become the local branch of the Softex programme – the most important programme of the federal Government aimed at fostering the establishment of software firms.

The Foundation was disbanded at the end of 2001 because of financial problems, even though it had produced some positive results. These included:

1. The setting up of a new venture in February 2000 by Petrobras' Revap (Henrique Lage Refinery), which resulted from the merging of five SMEs from the oil, chemical, biotechnology, instrumentation and industrial automation industries.
2. The setting up in 1993 of a firm of 10 employees in the aerospace sector, Engenharia Qualitas, specializing in the production of software and programming projects, quality control, aircraft maintenance and systems logistics for the aeronautical sector (see box V),

Box V. A success story in Pólo Vale

Initially dedicated to the domestic civil and military aviation market, Engenharia Qualitas has signed contracts with foreign companies such as Aertec of Spain for the implementation of an airport maintenance system. In the domestic market, the firm has customers in the civil aviation market, including Helibras (the helicopter producing firm), Embraer, and Pantanal Linhas Aéreas, a local carrier. In 1999, it signed a contract with Embraer for an estimated US$ 100,000 to develop systems for maintenance engineering and monitoring of costs for its entire fleet. In the aviation defence segment its main customer is the army. Sales reached approximately 500,000 real in 1999 and 1 million real in 2000.

Source: Authors

In 1998, the Foundation for Research Support of the State of São Paulo (Fapesp) allocated about US$ 30 million, over a period of six years, to support basic research and industry/university linkages. Fiscal incentives, such as local tax rebates, were also offered to new investments. These actions are strategic since a majority of the new enterprises are SMEs that are in no condition to meet operational requirements and, furthermore, have fragile self-financing structures.

In 1997, the municipal government of the city set up an agency – the Economic Development Secretariat (SDE) – with the objective of fostering local development and attracting new productive investment to the area. It targets the aerospace sector in particular, and it has developed (jointly with Embraer) a plan for the setting up of an aeronautical industrial complex. It is organized in an area of 200,000 m^2 where some 15 companies will be set up.

SDE and Embraer, with the support of the Federation of Industries of the State of São Paulo (FIESP), are also developing another project, a consortium for exporting, comprising SMEs in Paraíba Valley that supply parts and components to Embraer. Firms participating in the export consortium specialize in the areas of milling, metal processing, sub-assembly and treatment of materials. The main objectives of the consortium are both to make exports feasible by minimizing fixed costs and to increase the domestic production of components in the aeronautical supply chain. Twenty-six SMEs that potentially could take part in that consortium have been identified and 17 have been selected to participate in the pilot phase (see table 16). As

a result, a new venture has been created: High Technology Aeronautics (HTA). It is estimated that there is an export potential of between US$ 7 and 10 million/year, and that 35-40 per cent of the idle capacity of these firms could be used for manufacturing for export. The local government, together with the companies and entrepreneurs and workers associations, has been playing a major role in the promotion and development of the infrastructure for logistical and technology projects, which are strategic to the aeronautical production system. Also under way is a project with FIESP for the modernization of the Port of São Sebastião.

Also worthy of mention is the Programme for Expansion of the Brazilian Aerospace Industry (PEIAB), which was established by Embraer itself with the aim of strengthening the local aeronautical chain and raising the domestic content from the current 37 per cent to 50 per cent of value added. The programme is designed to focus on motivating partners to: (i) boost industrial capacity in Brazil, by setting up their own industrial units there or in association with national companies; and ii) contract parts of their industrial packages with Brazilian companies, offering and supporting those that are presently Embraer suppliers. The idea is to develop programmes with the federal, state and municipal authorities aimed at bringing to Brazil manufacturing and technological capacity currently not available in the country.

Table 16. Firms participating in the High Technology Aeronautics (HTA) Venture

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Firms	Origin of capital	Localization in the state of São Paulo	Area
Akaer	Local	São José dos Campos	Project engineering
Alltec	Local	São José dos Campos	Composites
Autômota Industrial	Local	Taubaté	Parts and components
Carpini & Marques Indústria	Local	Caçapava	Parts and components
Compoende Equipamentos para Ensaios e Serviços Especializados	Local	Tremembé	Project engineering
Elaine Ferreira Pereira	Local	São José dos Campos	Parts and components
LEG- Engenharia e Comércio	Local	São José dos Campos	Parts and components
LS Neves & Cia	Local	São José dos Campos	Parts and components
Metinjo Metalização Industrial Joseense	Local	São José dos Campos	Parts and components
Mirage	Local	São José dos Campos	Parts and components
New Plotter Engenharia	Local	Caçapava	Project engineering
Poly Cad Engenharia e Comércio de Informática	Local	São José dos Campos	Project engineering
SPU Indústria e Comércio de Peças	Local	Caçapava	Parts and components
Status Usinagem Mecânica	Local	São José dos Campos	Parts and components
Tecplas Indústria e comércio de Fibras	Local	São José dos Campos	Composites
Aeroserv	Local	Jacareí	Parts and components

Source: HTA - High Technology Aeronautics

The Association of the Brazilian Aerospace Industries (AIAB) was set up in 1993 with the objective of promoting a long-term policy of competitiveness for the sector. It is an organization of 25 firms targeting local technology development. In 1998, it produced a document on policies of competitiveness for the Presidency of the Republic, and in 1999, it presented a project for

technological development to the Programme for Support of Technologic-Scientific Development (PADCT) of the Ministry of Science and Technology. This project, which was approved, identified critical technologies and opportunities for businesses and is being implemented through partnerships between universities and local firms.

The local union, the Metallurgical and Engineers Union, has also been taking an active part in discussions on the direction of regional development, the processes of technological restructuring, privatization and its impact on skills. In turn, the institutional apparatus is geared to support research, basic, intermediate and higher technical education, and the formation of an associated technology culture for high-tech production. The local educational institutions have been able to meet the demand for highly skilled personnel. Their physical proximity to supplying companies and assemblers is also a positive factor. All this produces an industrial and innovative atmosphere that is extremely favourable to technological development.

The São José dos Campos area also enjoys logistical advantages due to its strategic location on the Presidente Dutra Highway between the two main centres of economic development in Latin America. It is 84 km from São Paulo and 321 km from Rio de Janeiro, has a 38 km natural gas pipeline delivery network and a 31 km optic fibre network at the disposal of companies located along the Presidente Dutra Highway. There is a basic band telecommunications station for transmission of voice, data and images, offering services such as international video-conferencing. Moreover, nearby are the Ports of São Sebastião (111 km), Santos (160 km), and the Port of Conchas on the Tietê-Paraná River is approximately 300 km from this area. The modernization of the São José dos Campos airport located 120 km from the capital of São Paulo, now being licensed to receive international cargo, was another important development for the region. Estimates are that monthly exports though the new airport could reach 2,000 tons, while imports could reach 1,000 tons. This corresponds to two daily flights of a Boeing 747-400 cargo aircraft.

4. Recent changes: Attracting foreign suppliers

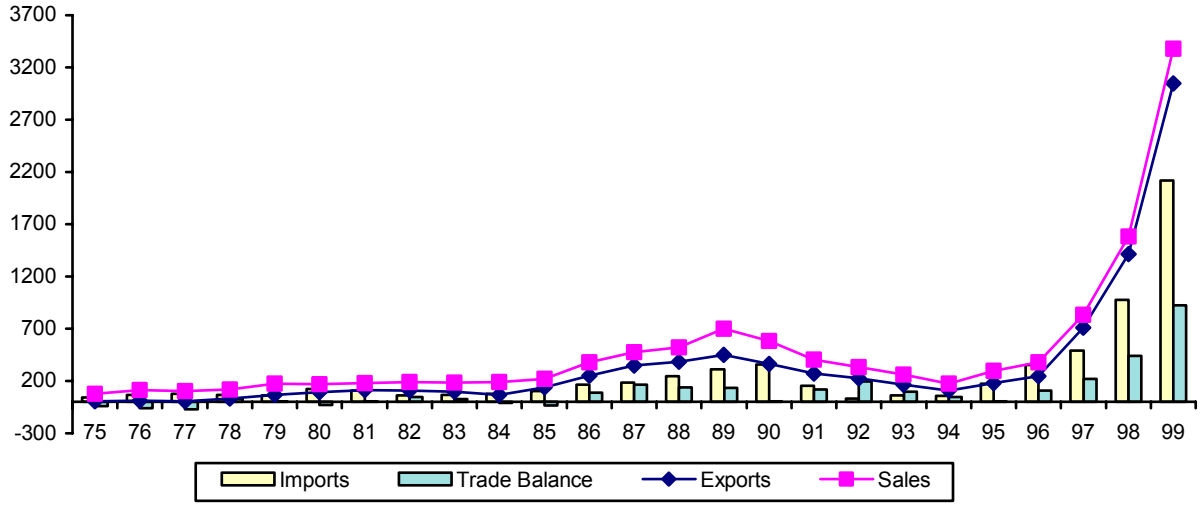
Embraer's overall strategy has resulted in successful sales and export performance over the years, as already discussed; imports also account for a large share of overall production, consistent with the worldwide trend in this industry. In the past, imports represented 60–70 per cent of production. More recently, however, with the rapid increase in production and world sales, an improvement in the trade balance has been observed, as shown in figure 4 below.

The *new supply policy* of Embraer has three main objectives:

1. Domestic production of parts, components and sub-systems, through the attraction of partner companies of the ERJ-170/190 programme to the vicinities of the São José dos Campos plant;
2. Reduction in the number of external and local suppliers, establishing new norms and parameters for the composition and integration of its supply chain. The ERJ-145 programme had around 400 suppliers, while the new ERJ-170/190 family will have approximately 40 suppliers; and
3. Building new types of supply relationships and managing flows between the suppliers of systems, parts, components, structures and technological services, through a pattern of "technological packages".

Figure 4. Embraer: Sales, exports, imports and trade balance, 1975-1999

(Million real)



Source: Embraer

In practical terms, the first-level suppliers will be responsible for the aggregation of a group of sub-systems that will make up a "technological package" of the aircraft, to be supplied and integrated into the final phase of the assembly line at Embraer.

The historical experience of technology transfer by Embraer to national suppliers has brought mixed results. The AMX programme is a case in point. During the 1980s, Embraer had identified and nurtured, through the special PIC programme (Industrial Supplementary Programme) of the Ministry of Aeronautics (Maer), about 20 domestic companies (among them, Elebra, Tecnasa, Aeroeletrônica, GE/Celma, Rolls Royce motors, EDE, Modata, ABC dados, Pirelli, Engetronic), mostly located in the area of São José dos Campos, to supply components and electronic systems for the consortium between Embraer and the Italian company Aermacchi. At present, of the initial group of companies only four remain: Elebra, Aeroeletrônica, GE/Celma, and Tectelcom (formerly Tecnasa, presently under bankruptcy proceedings). In this case, there was a deliberated regression in technological development, as well as losses in technological know-how and international markets.

The new Embraer philosophy and technological strategy is focused mainly on the essential competencies. In the past, software and technological systems were developed largely within the company but now they are ordered, purchased or developed jointly with "soft houses". One example is Fibra Forte, a small company (of five employees) located in the São José dos Campos area, staffed with ex-employees from Embraer, which develops the engineering software used in the management of project activities.

The development of the new family of Embraer jets – ERJ-170, ERJ-190-100 and ERJ-190-200 – opened up opportunities for attracting new foreign investment and foreign companies in Brazil. The transfer of some suppliers of the programme to the area of São José dos Campos, close to the company's factory, is part of its strategic plan to operate under a *just-in-time*/*kanbam*[12] philosophy from the year 2001 onwards.

Information supplied by Embraer confirms that 17 of its international partners are interested in setting up local subsidiaries in Brazil to benefit from the proximity to Embraer (see table 17 in Annex); these companies include:

- C&D Interiors, one of risk partners of the ERJ-145 programme;
- Parker, which has a factory in Jacareí where it produces systems for the automobile industry;
- The German company Liebherr, which reached an agreement with the Equipment Division of Embraer (EDE) for opening a new company, ELEB, in São José dos Campos; and
- Latecoere that has already signed contracts with companies located in São José dos Campos for the supply of engineering services and technical support.

The report of the Embraer PEIAB team estimates that the new investment already confirmed will result in the direct generation of 1,850 new local jobs with forecasted annual sales of US$ 320 million. In this new stage, industrial investment of the order of US$ 280 million is planned: US$ 80 million in engineering services, generating 250 jobs; US$ 150 million in local production of parts, creating 1,000 jobs; and US$ 50 million for the installation of partners in Brazil, resulting in another 600 new jobs (see box VI).

Box VI. Potential for local production

Embraer believes there are several intermediary products (and technologies) that could be manufactured locally, which at present are imported. Among them,

- Sub-set and structure assembly (fuselage rings and wing);
- Connection bars, autoclave services, thermoforming and vinyl gluing;
- CNC stamping of 4 and 5 axes, acrylic moulding and plate anodizing;
- Milling, tapestry and manual impregnation;
- Chemical finishing; and
- Special processes: Shot-pin conforming.

As for technical services, in general, Embraer estimates that local production could be developed in the areas of:

- Project engineering in general;
- Systems and process controls, administration and use of equipment;
- Architecture and integration of mechanical and electronic systems, for example; and
- Quality and instrumentation services and software, among others.

Source: Embraer

[12] Kanbam: methodology of production optimisation.

CONCLUDING REMARKS: THE POLICY PERSPECTIVE

Today, Embraer is one of the few Brazilian companies with ample capabilities for innovation in the complete technological learning process. It accords great importance to the process of consolidation of technological knowledge, its transformation and dissemination through the company's communication channels. In addition, Embraer has highly qualified personnel through the mechanisms of learning-by-doing, especially in the manufacturing process, in the assembly of fuselages and in systems' integration. The dynamics of learning uses complex products, new materials, software and avionics resulting both in efficient operating practices and more effective maintenance and adaptation, which in turn result in product improvements. And finally, it promotes learning-by- interacting that derives from the interaction and institutional administration between the partners and the suppliers linked by information, goods and services.

The cycle of technological innovation is now perceived as a business dynamic not exclusively restricted to the routines of R&D. This is because the technological learning processes have demonstrated the importance of interdependency and intercommunication. In other words, the organization needs to create an interdependence between technical production, human resources, financial, economic and marketing spheres while at the same time also satisfying market demands. This implies the merger of many functional activities at Embraer. A further strategic change for Embraer is needed, based on implementing a management model that emphasizes learning, innovation and knowledge. In this respect, studies for the implementation of a project for creating a "corporate university", i.e. a private university owned by the firm that will graduate scientists and engineers with the appropriated skills to its needs, has already been initiated under the responsibility of the human resources department.

The focus adopted by the new administration is characterized by sophisticated analysis using indicators of performance, profitability, client satisfaction, and the monitoring of change and future market transformations. This requires the establishment of a set of formalized and institutionalized mechanisms to generate, register, analyse and interpret information that is considered strategic and vital in the context of high competition, swift obsolescence of the technological frontiers and market uncertainty. The competitive strategy of the company has been articulated mainly through studies concerning aircraft demand conducted by outside consulting companies. In 1998, a Market Intelligence area was created with the aim of internalizing these studies within the culture and competitive strategy of Embraer itself. Basically, they include the study of market trends through the quantification of the global demand of aircraft using "top down" technical analysis, which consists of evaluating elements such as fleet size, number of aeroplanes in operation and fleet condition, sales development, backlog, sold and undelivered units, and sales forecast. The other method for quantification uses the "bottom up" approach, and consists of a direct approach to the customers, and their real interest in a new product.

Embraer is responsible for the employee training, technical monitoring and for the technological learning processes of its subcontractors. It does this by sending Embraer engineers to them to impart the necessary know-how (see box VII).

Box VII. Cooperative of Engineering Services (SERCO)

The 1995 experience of the Cooperative of Engineering Services (SERCO), comprising ex-employees of Embraer and other previously State-owned firms in the military area (such as, Avibras and Engesa), is one of the most interesting in São José dos Campos. The services rendered by the Cooperative provided a crucial alternative for Embraer's survival, since there was a surplus of professionals on the market due to the crisis in the civil aerospace and military defence sector in the first half of the 1990s. SERCO is made up of work nuclei organized by segments of commercial performance; it consists of eight services nuclei distributed among the cooperative partners: aerospace and infrastructure, quality and human resources, civil works, safety and occupational medicine, machinery and IT structures, electro-electronics, industrial automation and export and import services.

According to a study conducted by Mendonça (1997:44), in 1996 SERCO had 130 cooperative partners registered in the municipal government as autonomous professionals. The Cooperative signed contracts with multinational corporations that participated in the ERJ-145 programme, rendering design services and development inspection. Embraer hired services from this Cooperative, ranging from microfilming of drawings and documents to maintenance and checking of documents. The monthly average revenue was in the range of US$ 250,000 in 1996. With the sustained recovery of the aeronautical sector, SERCO's revenue grew twentyfold reaching a total of US$ 5 million in 1998. The substantial growth of this Cooperative is related mainly to the boost it received from Embraer and its suppliers and from the global air transport sector, at which the services that meet the requirements of new markets, such as IT and electronic documents processing, are aimed.

Source: Authors

Embraer's successful strategy of competition and innovation in the 1990s occurred during a period rupture in government support for CTA and other local technological institutions. The Brazilian Government cut down its resources for government-sponsored science and technology institutions and this had some impact on the local innovation system. As a matter of fact a problematic cooperation pattern has emerged between Embraer and the local R&D institutions. Embraer's cooperation and research relationships with CTA used to be more organic in the days of total government control, but currently are limited to aircraft certification and approval. Even with other universities, such as the São Carlos School of Engineering and the Polytechnic School, contacts are only on an informal basis, contrasting with European and North American experiences where a more structured relationship of firms and R&D centres is found.

In the 1990s Embraer managed to capture an important share in the world market for aircaft and became a member of a very select club of competitive firms in this sector in a period when the Brazilian federal Government's policy towards the industrial sector was almost non-existent. Without entering into a wider discussion about general industrial policy, it is important to note that all the successful experiences of the aircraft industry point to large government support in several different ways. This is the case with Boeing and McDonnell Douglas of the United States, the Airbus European Consortium and the Canadian firm Bombardier.

However, there was an important Brazilian Government programme, which helped Embraer in the 1990s. Besides the virtues of the ERJ-45, its price and financing scheme were important in American Eagle's decision to purchase the aircraft. The sales operation had the support of credit lines provided by the Brazilian Economic and Social Development Bank (BNDES) through its Finamex programme for export financing. The financing arrangement was the decisive factor in the success of the deal, covering up to 100 per cent of the value of the operation at internationally comparable interest rates and with a repayment period of up to 15 years. The loan of US$ 1 billion granted by BNDES for the export of 40 ERJ-145 aircraft was the largest ever approved in the entire history of the bank. This scheme was part of a government export support programme – Programa de Financiamento às Exportações (PROEX) created by the Government of Brazil on 1 June 1991, by Law 8187/91. It provides export credit to Brazilian exporters, either through direct financing or interest equalization payments. Under the direct financing scheme, the Government lends a portion of the funds required for the transaction. Under interest equalization, underlying legal instruments provide that the National Treasury "grants to the financing party an equalisation payment to cover, at most, the difference between the interest charges contracted with the buyers and the cost to the financing party of raising the required funds (Resolution 2380/97 of the Brazilian Central Bank, 25 April 1997).

The success of Embraer and the use of these policy mechanisms led to a dispute between Embraer and Bombardier wherein Bombardier accused the Brazilian Government of subsidizing the manufacture of aeroplanes. On 18 June 1996, Canada requested consultations with Brazil at the World Trade Organization (WTO), under Article 4 of the Agreement on Subsidies and Countervailing Measures and Article 4 of the Understanding on Rules and Procedures governing the Settlement of Disputes, regarding "certain export subsidies granted under the Brazilian PROEX to foreign purchasers of Brazil's Embraer aircraft".[13]

The possibility for the type of investment outlined in Chapter V materializing is certainly dependent on some important changes in government industrial policy. The federal Government has been allowing state governments to compete almost entirely through the offer of fiscal incentives (tax breaks or significant reductions in the state level taxes), without any interference by the central authorities, to attract foreign firms to their regions. However, such competition between the state governments plays limited role in attracting the type of new investment needed by Embraer.

In order to analyse policy alternatives it is useful to discuss briefly the role that the Government played in supporting Embraer's establishment. The federal Government supported Embraer's sales through a programme of financing its exports. As a developing country firm,

[13] See Canada's request for consultations at WTO (WTO document WT/DS/46/1).

Embraer had experienced difficulties finding international banks and financial institutions willing to provide the financial engineering needed to sell aeroplanes. In this type of market, sales tend to be coupled with a financing package. The importance of the programme of financing exports (PROEX) of the Brazilian National Economic and Social Development Bank (BNDES) was that it not only provided the financial package, but also, and equally important, a framework under which local interest rates were equated with international interest rates. As mentioned above, this kind of incentive was heavily contested at the WTO by Embraer's immediate competitor Bombardier of Canada and by the Canadian Government.

The other significant policy initiative of the federal government, that partly helped Embraer, has been the fiscal incentive to stimulate technological upgrading. Under this policy, industrial and agricultural firms are allowed to rebate the outstanding income tax on account of *R&D* expenditures and the value added tax on equipment acquired for *R&D* activities, as well as accelerated depreciation allowance for equipment and instruments acquired for *R&D*.

There are also some credit lines by Finep, the technology bank of the Ministry of Science and Technology, but this is not an excellent option, given the high interest rates that characterize the Brazilian financial system. As already mentioned, there have also been several attempts both from the state of São Paulo and from the city of São José dos Campos to provide help.

One of the more important policy mechanisms that could help the development of the local innovation system would be a series of mechanisms to foster the growth of small high-technology firms around Embraer. In fact all major competitors of Embraer benefit from this type of support provided it is not inconsistent with WTO rules.

It may be concluded that federal policies and state actions contributed to the success of the modern phase of the Brazilian aircraft industry. The federal Government offered solid and continuous support to Embraer at the time when it was a government-controlled enterprise through budgetary allocation of sufficient financial resources for S&T infrastructure and procurement. To a large extent, it was through procurement that technological learning was made viable and feasible. This government policy, particularly that of the Ministry of Aeronautics, imposed on outside partners associated with Embraer the requirement of local production to foster people-to-people technology transfer.

In Embraer's present situation as a private company, the federal Government continues to support Embraer's sales through its programme of export financing and it has been able to implement a supporting programme, namely the Programme for Expansion of the Brazilian Aerospace Industry.

In terms of international trade rules, civil aircraft is also the subject matter of a plurilateral Agreement on Trade in Civil Aircraft, part of the Tokyo Round Agreements of the General Agreement on Tariffs and Trade (GATT), that applies only to its signatories. Brazil is not a signatory of the Agreement but it has observer status. Due to the fact that civil aircraft is subject to this plurilateral agreement, certain provisions of the Agreement on Subsidies and Countervailing Measures (SCM Agreement) (Article 6.1 (a) and (d)- Serious Prejudice -, and

Article 8.2 (a) Non-Actionable Subsidies)[14] did not apply to civil aircraft. However, the provisions of these Articles have lapsed on 31.12.1999. Subsidies otherwise applied to the aircraft industry are subject to compliance with the provisions of SCM Agreement.

Finally, Embraer's experience in cooperative agreements involving transfer of technology could be considered an interesting example of successful acquisition of technological knowledge in conformity with international trading rules.

[14] Article 6.1 (a) and (d) – Serious Prejudice – and Article 8.2 (a) Non-Actionable Subsidies of the WTO SCM Agreement explicitly exclude civil aircraft from these provisions.

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ANNEX

Table 17. Partners of the ERJ/170/190 Programme Intending to Invest or to Settle in Brazil

Company	Country of origin	Supply	Contractual commitment	% National Supply	Status
Parker Hannifin Corporation	USA	Flight Control, Fuel and Hydraulic System	Installation of plant close to Embraer	15%	The company will count with its local subsidiaries in SP and Jacareí. It evaluates the construction of a new building in São José dos Campos
Hamilton Sundstrand	USA	Power System/ APU. Tail Control System, Air Control System	Seeking new opportunities and domestic partners	2%	Establishment of an office in Brazil; Contract signed with Dynamic in Campinas for rendering of engineering services and technical support in the amount of Real$ 180,000 until Dec/2000.
General Electric Aircraft Engines	USA	Motor/Nacelle	Group assembly	2%	GE controls Celma, and is analysing the viability of assembling motors and rendering maintenance and repair services. It is also studying the conditions for purchase of motor components directly from Celma or Brazilian companies.
Latecoere	USA	Central Fuselage I Central Fuselage III / Doors	Production of parts and/or engineering services in Brazilian companies	5%	Establishment of Latecoere do Brasil. Has entered contracts with Dynamic in Campinas, for rendering of engineering services and technical support of US$ 160,000 until Dec/2000. Signed a contract with Suprisul - São José dos Campos - for lease of IT equipment, total in the amount of US$ 425,000. Contract with Akros (S.J. dos Campos) for rendering of engineering services US$ 690,000/year for 5 years. It is evaluating the companies Aeroserv and ELEB (S.J. dos Campos) as part of its network of suppliers.
Gamesa Aeronáutica	Spain	Rear fuselage and Empennage	Use of Brazilian companies for material purchase and/or services limited to US$500,000/yr.	--	The company evaluates new national companies for the supply of composite materials for the ERJ-170/190. It maintains a contract with Dynamic in Campinas for the allocation of engineering equipments and technical support over US$ 7,000 until Dec/2000.
Liebherr	Germany	Landing gear	Production of the Landing gear	38%	Entered a joint venture with EDE (former division of Embraer) forming a new called company ELEB.
Sobraer S.A. (Brazilian subsidiary of Sonaca S.A.)	Brazil	Slat/Central Fuselage II (Manufacture)	Production of parts and/or engineering services in Brazilian companies	--	Implantation of an industrial unit in S.J. dos Campos. Sobraer will accommodate the junction of the pylons in the rear fuselage supplied for the ERJ-135/145 programme and its final assembly, in a process that will be transferred progressively from the Belgian head office to

					the Brazilian subsidiary. Presently made in Belgium, the final assembly of its segments supplied for the ERJ-135/145 programmes is made possible through services rendered by a contract signed with Serco (S.J. dos Campos), foreseeing the use of 35 employees/month for 1 year, with a total of 50,000 work hours. It studies the viability of the production, in Brazil, of approximately 250 milled parts of the Central Fuselage II of the ERJ-170/190 programme.
C&D Aerospace	USA	Interior	Installation of a Plant in the Area of São José dos Campos	10% in the first year and 20% starting from the second year	C&D do Brazil was Established in 2000, in Jacareí. Their activities will begin with support to the ERJ-135/145 programme, foreseen to begin of production of Overhead Bins and PSU structures for first quarter of 2001. The accumulated investments in industrial plant, improvements, equipment and personnel and development of infrastructure are estimated at US$ 3,100,000.
Kawasaki	Japan	Wing (fixed leading edge, fixed trailing edge, pylon, control surfaces	Studying partnerships with domestic companies	4%	Kawasaki is analysing the feasibility of looking for domestic partners to reach a 4% national content.
Honeywell	USA	Avionics	Expansion of the repair workshop at Embraer and intention of establishing support centre for operators of Latin America	--	Installation of support centre for training of operators in Latin America
NMF	Canada	Covering panels	Factory implantation in Brazil.	--	The decision to install a plant in Brazil depends on the minimization of the tax burden. Company studies point to investments of US$ 18,000,000 in the implantation of the Brazilian factory.
Figeac Aero	France	Supply of Covering Panels and Wing Rib	Implantation of a subsidiary in Brazil	--	The intention of the company is to invest US$ 12,000,000 in the assembly of a subsidiary in Brazil for the supply in partnership with Embraer of Covering Panels and Wing Ribs.
Aeromot/Cyclone Aviation Products Ltd.	Israel	Implementation of new technologies in aviation production	Investment in new technologies together with national companies	--	A contract was signed between Cyclone and the Brazilian Aeromot (Rio Grande do Sul) for the implementation of technologies for structural assembly of metallic and composite materials, milling forming of metallic plates, superficial and thermal treatments. Investments of around US$ 10,000,000 to US$ 15,000,000 are planned.
Goodyear	USA	Tires	Reactivation of the industrial park for the production of tires for the aeronautical industry	--	Reactivation of its industrial unit in São Paulo, seeking initially to meet the ERJ-135/145 programme, and later, the expansion for supply to the ERJ-170/190 programme. The intention is to produce about 20 different sizes of tires to meet the aircraft requirements of Embraer, such as: Brasília, AMX, ALX and Tucano. The production expectation is around 25,000 tires a year in 2003, with a sales

					forecast of US$ 6,000,000.
Pilkington Aeroespace	USA	Production of Transparencies / windows	Adaptation of an industrial unit in São José dos Campos	--	The company is adapting an industrial unit in São José dos Campos, seeking initially the production transparencies /windows for the ERJ-135/145 programme, and later, the expansion for supply to the ERJ-170/190 programme. This unit has a built area of 1,950 m2, where it intends to have from 60 to 70 employees dedicated to the aerospace sector. The technology transfer should occur, according to Embraer, in a year.
Elano Corporation	USA	Project and Manufacture of tubes and metallic ducts for aviation engines and air conditioning systems and aircraft pressurization	Establishment of partnerships with Brazilian companies, or installation of own subsidiary in Brazil	--	The Elano company is subsidiary of GE Aircraft Engines. With the objective to meet to the needs of the Embraer programmes, Elano intends to establish partnership with Brazilian factories, or in case of viability, invest in the establishment of own subsidiary in place that is economical and logistically more viable to meet the Embraer programmes.
Labinal	USA	Supply of Electric Cabling	In phase of viability studies	--	Labinal is accomplishing viability analyses for the establishment of partnership with Brazilian company or installation of a subsidiary in Brazil.

Source: Embraer - PEIAB Brazilian Aerospace Industry Expansion Plan