HIGH TECHNOLOGY IN DEVELOPING COUNTRIES: ANALYSIS OF TECHNOLOGY STRATEGY, TECHNOLOGY TRANSFER, AND SUCCESS FACTORS IN THE AIRCRAFT INDUSTRY

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Abstract: Economical development is highly related to technological development. It is therefore not surprising that many of the industrially developing nations follow explicit strategies to increase their technological competence level. Industrially developing countries may even pursue a strategy of developing high technology competencies. This paper analysis the strategies of some developing countries in a particular high technology industry: the aircraft manufacturing industry. The focus is on Brazil, China, Indonesia and Romania. The approach that each of these countries has followed towards developing an indigenous aircraft manufacturing industry is described. Next, the current status of these national industries is analysed. It is concluded that industrially developing countries are stuck in a very difficult situation. It is extremely challenging for industrially developing countries to develop a competitive position in this high technology and global industry. The analysis shows that it is questionable whether technology transfer is effective. As a consequence it may not be a good strategy for industrially developing countries to follow a leapfrogging technology strategy. Instead a more incremental approach towards technological development may be more appropriate.

Keywords: International technology transfer, technology management, international management, public policy.

1 Introduction

About the aircraft industry it has been stated that "few other industries combine in as large a measure a crucial role in national security, a major contribution to national economic health and foreign trade, and a flagship role in the global posture of technological leadership" (U.S. Committee on Technology and International Economic and Trade Issues, 1985, p. 18). It is therefore not surprising that many countries have made the aircraft manufacturing industry a strategic industry. Despite these efforts, not many nations are successful in building and selling aircraft. Examples of illustrious companies that have, voluntarily or involuntarily, given up manufacturing commercial aircraft are Lockheed of the USA, Saab of Sweden, Fokker of the Netherlands,

McDonnell-Douglas (MDD) of the USA and British Aerospace (BAe) of the UK. Other companies have been trying, some for decades, to establish a position in the industry but have so far been unsuccessful. These include Indonesian Aerospace (IAe) and the Chinese Aviation Industry Corporations (AVIC I and AVIC II). Why is it that so many companies and/or nations aspire to build and sell aircraft? And, why is it that so many fail? It is noteworthy that the current attempts of companies to establish themselves in the aircraft industry are from industrially developing countries. But with so many failures of companies in industrially developed countries to sustain a position in the aircraft industry, will these companies from industrially developing countries have a chance? This paper will address these issues by first examining what it takes to compete in the commercial aircraft industry. Then four case studies, i.e. Brazil, China, Indonesia and Romania, are analyzed to determine their technology strategies and technology transfer approaches and to determine how they score on the key success factors.

2 Competing in the aircraft manufacturing industry

To get insight into the characteristics of the aircraft manufacturing industry we analyzed a range of aircraft industry studies (Phillips, 1971; U.S. Committee on Technology and International Economic and Trade Issues, 1985; Hayward, 1986; Todd and Simpson, 1986; U.S. Department of Commerce, 1986; Yoshino, 1986; Mowery, 1987; Newhouse, 1988; U.S. International Trade Commission, 1993; Eriksson, 1995; Bilstein, 1996; Lynn, 1998; U.S. International Trade Commission, 1998). Although most of these focus on large commercial aircraft, they provide a good starting point to get insight into the regional aircraft manufacturing industry. We also analyzed industry publications such as Aviation Week & Space Technology, Flight International and Interavia since 1993. The literature reveals a combination of characteristics that distinguishes commercial aircraft manufacturing from many other industries.

1. The production of aircraft requires skilled labor. It is further characterized by low production volumes and long production lead-times.
2. Aircraft have high value (sales prices), are sold infrequently, and in relatively large amounts. Due to the high value, much money is tied up in production. Aircraft are also often ordered in ‘large’ quantities.
3. Selling aircraft requires a global sales and after sales network, financial packages for customers, and it requires dealing with a highly politicized process.
4. Technology has been a key determinant in the industry, therefore companies competing in this industry will have to be able to develop state-of-the-art new aircraft, typically requiring large and long-term R&D investments.
5. Demand for commercial aircraft is cyclical. The cyclical effect for regional aircraft is less prominent than in large aircraft because the market is less mature. Cyclical demand places a burden on companies because they need to have sufficient money to survive the cyclical downturn.
6. There is reasonable doubt about the profitability of aircraft production. Average ROI for the industry is low and many companies have been forced to leave the market. In the large commercial aircraft industry both Airbus and Boeing, the only two companies in that market segment, are known to have incurred heavy losses in the mid-1990s. Many authors view sales of 600 aircraft as a signal that the product has

been successful. Since 1952 there have been only 11 commercial jet aircraft types of which more than 600 units were sold (Jet information services, 2003).

Conclusion: the aircraft manufacturing industry is an industry where economic pay-offs are on average low, where the risk is high that not enough aircraft are sold to be profitable, where large amounts of money have to invested in the development of an aircraft, where large amounts of money are tied up during production, where the incomes generated from sales have a substantial time lag, and where customer support essentially has to be available any where in the world. All in all, this means that having the capability to produce an aircraft is not nearly enough to survive. In addition, companies need to be able to design aircraft, establish a global support presence, and they need substantial financial resources to survive long time periods during industry down-turns.

3 Cases

Four companies/countries are analysed to determine how these key factors influenced the success or failure of regional aircraft producers in industrially developing countries. The manufactures chosen are Romaero, IAe, AVIC and Embraer.

3.1 Romaero (Romania)

In 1968, the Romanian government targeted the aircraft industry as high-priority economic activity and established the Centrul National al Industriei Aeronautice Romane (CNIAR) as an umbrella organization under the auspices of the Ministry of Machine Building Industry (Todd and Simpson, 1986). At that time, Romania was a communist oriented society. In 1968 Romania purchased six BAC 1-11 jet-aircraft from the British Aircraft Corporation (BAC) in the UK. As part of the offset agreement Intreprinderea de Avioane Bucuresti (IAvB) started license manufacturing the Britten-Norman Islander 8-passenger propeller-aircraft. The initial license was for the production of 215 aircraft. In 1975 a new agreement was reached. This time Romania bought five BAC 1-11 aircraft. As offset, the Islander license for IAvB was extended and IAvB started manufacturing parts, about 8.5% of the airframe, for the BAC 1-11.

In the late 1970s the Romanian government was looking for an extension of its aircraft manufacturing capabilities and wanted to manufacture a short range aircraft and a medium range aircraft. The Romanian choice for the short range aircraft was the VFW 64, a German/Dutch aircraft but negotiations ended when a high level Romanian official fled from Romania. For the medium range aircraft the Romanian government selected two options: the French Caravelle and the DC-9 from the US. However, both manufacturers (countries) were unwilling to enter into counter-trade agreements. The UK was willing to enter into counter-trade agreements and offered the possibility of a license agreement for the HS-748, a 50-passenger propeller-aircraft. Romania, however, wanted a jet-aircraft. In 1978, an agreement was reached between Romania and BAe (a company that was formed in 1977 through the merger of BAC, Hawker Siddeley Aviation, Hawker Siddeley Dynamics and Scottish Aviation). A license for the production of 82 BAC 1-11 aircraft until 1996 by IAvB was given and three BAC 1-11 aircraft were purchased. The BAC 1-11 is a 90 to 110 passenger jet-aircraft. BAe was willing to license the BAC 1-11 because it considered the BAC 1-11 to be at the end of its life cycle. BAe also needed money to

support the further development and production of the HS-146. The license also allowed BAe to close its manufacturing line and transfer responsibility for spare parts production to IAvB. The Romanian purchase of the three BAC 1-11 aircraft provided short-term production continuation which was essential for Romanian training opportunities.
The production technology of the BAC 1-11 was planned to be transferred in eight phases containing 22 aircraft. The first seven phases each contained three aircraft. For each subsequent phase a higher percentage of the airframe was to be produced in Romania. The 8th phase contained one aircraft, the 22nd aircraft, which was to be completely manufactured in Romania by 1987. The technology transfer program was faced with delays from the start, e.g. the construction of the factory was delayed. A very important factor in the delays was the worsening economic situation of Romania during the mid-1980s. Romania did not have enough money, especially foreign exchange, available. This affected training opportunities in the UK, technical assistance in Romania, transportation of documentation and equipment, and the purchase of BAe parts. To circumvent the latter, the Romanian government tried to purchase parts from local suppliers but these were not able to meet the quality requirements. Consequently, production was frequently shut down to wait for sufficient funds so that BAe parts could be purchased. The technology transfer became even more complicated when BAe decided to stop its BAC 1-11 manufacturing lines in 1989 which affected training opportunities. Another complicating factor was changing noise regulations. IAvB was considering re-engining the BAC 1-11 but did not have design authority. BAe was unwilling to financially commit itself and other potential investors needed Romanian government guarantees. The World Bank regarded this as debt and did not allow the Romanian government to increase its debt for the aircraft industry.
By 1992 the technology transfer program was terminated. At that time only 9 aircraft were completed. The completed aircraft received the equivalent of the UK's aviation certification (CAA) and were therefore viable for export. Nevertheless, all were sold to customers in Romania.
In 1990 IAvB was renamed Romaero. Romaero's management concluded that the global number of manufacturers of complete aircraft was reducing, that airlines demanded a family of aircraft and product support 24 hours a day anywhere in the world. The management concluded it would not be able to succeed. The number of suppliers of aircraft parts, however, was increasing and in 1994 Romaero decided to change its strategy. It considered that it could have a place in the commercial aircraft industry by manufacturing parts and/or assemblies. Since then Romaero has been manufacturing parts for well known aircraft manufacturers, including Boeing, British Aerospace and Bombardier. Romaero has also continued the production of the Islander aircraft. Since 1997, this has extended into production of the Defender, a derivative of the Islander.

Conclusion: Romaero started with the licensed manufacturing of an 8-passenger propeller aircraft in which it was successful. It then tried to increase its manufacturing expertise by licensed production of a 100-passenger jet-aircraft. It succeeded only partly, i.e. the completed aircraft were certified by Western aviation authorities but these were only partly manufactured in Romania. Serious problems with the BAC 1-11 manufacturing were caused by financial constraints. Although the intention of the license agreement was to sell 42 of the 82 aircraft outside of Romania, it is questionable whether this would have been successful considering the market size. BAC/BAe had been selling the BAC 1-11

since 1965 and considered the product at the end of its life-cycle when it entered into the license agreement in 1978. Romaero has not attempted to design and develop medium/large aircraft on its own. In 1994 Romaero changed its strategy and is now focused on manufacturing parts and assemblies for aircraft manufacturers.

3.3 IAe (Indonesia)

Industri Pesawat Terbang Nusantara (IPTN) was formed in 1976 by the Indonesian government to provide a vehicle towards Indonesia's industrial transformation. Indonesia provided IPTN with a domestic market since it has the fourth largest population in the world and with 17,000 islands spread over three time zones, it is heavily dependent on air transportation. IPTN developed a four phase long-term plan. The four phases were:

1. Technology transfer through licensed production, i.e. the use of existing production and management technologies to produce goods already on the market.
2. Technology integration, i.e. the use of existing technologies in the design and production of completely new products.
3. Technology development, i.e. the further development of existing technologies and investment in new technologies.
4. Large-scale basic research to support the first three phases and to defend the technological superiority already attained.

The first phase was initiated in 1976 with the license agreement to produce the CASA C-212 Aviocar, a 24-passenger turboprop aircraft. The C-212 Aviocar was designed by CASA from Spain and first flew in 1971. The license program was similar in set-up as the BAC 1-11 deal in Romania. The first Indonesian C-212 Aviocar was assembled from major components and subsequently the Indonesian content was increased until around 1987 IPTN was able to completely manufacture the C-212 by itself (Eriksson, 2003). The first Indonesian C-212 Aviocar was built in 1976 and by the end of 2002 approximately 94 have been built in Indonesia, all primarily sold to Indonesian customers. By October 2003, more than 460 C-212 Aviocar were sold by CASA in 42 countries.

The second phase was initiated in 1979 with the announcement that IPTN and CASA were jointly developing the CN-235. The CN-235 is a 44-passenger turboprop-aircraft. The first Spanish built CN-235 flew in November 1983. The first Indonesian built CN-235 flew six weeks later in December 1983. By 1996 the Indonesian built CN-235 still had not gained FAA/JAA certification, which is essential for export. The Spanish built CN-235, with more than 50% Indonesian content, were FAA/JAA certified. The problem was a lack of US/Indonesian bilateral airworthiness agreement, plus the time being taken to convince the FAA of the thoroughness and independence from IPTN of Indonesia's certification procedures. By December 2002 about 47 CN-235 had been produced and delivered by IPTN compared to about 250 by CASA. Although some Indonesian CN-235s were sold to foreign military forces, no aircraft were exported on purely commercial grounds.

In 1989 IPTN announced the third phase, i.e. the development of its first fully indigenously designed aircraft; the N-250. The N-250 is a 68-passenger turboprop-aircraft which utilizes modern technology such as fly-by-wire. The N-250 development is substantially aided by Western assistance. The first aircraft was rolled out in November 1994, about a year behind original plans and first flight was in August 1995. In 1994 there were plans to open a second N-250 assembly line in the US. Producing in the US was considered because it offered a large market for the aircraft, would allow US investors to

participate, it would cut cost because a majority of the N-250's components are from US suppliers, and it would make it easier to get FAA certification. IPTN planned to get FAA certified by 1997 for first deliveries of the aircraft in 1998. Immediate problems were encountered. The FAA was particularly concerned about the level of Indonesian certification experience and questioned the ability of Indonesia's airworthiness authority (DGAC) to certificate an aircraft as complex as the N-250. The FAA stated repeatedly that the Indonesian government's attention had not focused enough on the development of a 'world class' regulatory body. Another problem was the prototype. This was only a 50-seat aircraft which could not be used to achieve FAA/JAA certification. IPTN planned to use the correct sized 2nd until 4th prototypes for achieving western certification. By mid-1996, US production plans changed in producing a stretched 72-passenger version, the N-270. The first N-270 was to be delivered in 1999. By 1997 the FAA indicated that it would not recognize the 2nd N-250 prototype as a validation aircraft because of a lack of component document conformity. Following this IPTN enlisted a team of European aerospace consultants to try to help achieve JAA certification. The JAA, unlike the FAA, does not require a bilateral treaty with Indonesia. In 1997 IPTN signed a marketing and technical joint-venture agreement with a German group to market and assemble the N250 in Germany.

The circumstances changed by early 1998. The IMF, in order to improve Indonesia's economic situation, ordered that no more financial support and privileges were to be given to IPTN. Subsequently IPTN started looking for outside investors and didn't produce a fourth N-250 prototype. In early 1999, IPTN, due to continued financial troubles started cutting its 15,000 workforce. By mid-2000, it had cut a third of its workforce. In August 2000, IPTN changed its name to Indonesian Aerospace (IAe) and it started looking at China to provide the remaining $90 million in funding to complete the N250 certification. In July 2003, IAe's offices were closed for six months due to the continued financial troubles. Despite spending more than $650 million on the N-250 development and claims of firm orders, some from foreign carriers, by 2004, the 3rd prototype was still under production, no production had taken place in the US and Germany, certification was not achieved and consequently no N-250 aircraft has yet been sold.

Although the third phase has yet to be completed, in more prosperous times IPTN entered its fourth phase. In 1995, at Indonesia's 50th anniversary of independence, a $2 billion development program for an 80-130-seat regional jet, the N2130, was announced. Similar to the N-250 the N2130 would be designed with help from Western companies. In June 1996 IPTN accelerated its manufacturing schedules for the N2130. First deliveries were moved forward two years, to 2004, based on the strength of the pre-market surveys, the launch of the MD-95 by MDD and the anticipated launch of a 100-seater (AE-100) from China. IPTN estimated that there were domestic requirements for around 150 aircraft. In March 1997, IPTN decided to focus on a larger-aircraft family with seating for between 104 and 132 passengers. In 1998, as described earlier, the IMF constricted the Indonesian government's financing of IPTN. As a consequence IPTN started looking for international investors. By February 1999, local shareholders in the N2130 program demanded a refund of their investment arguing that they were forced into making the investment by the government of ex-president Suharto. In November 2003, IAe revealed a five-year survival plan. The plan identified a 19-seat passenger aircraft as a new manufacturing project and

there was no mention of the N-250 or the N-2130. IAe continues to manufacture parts for western aircraft manufacturers such as Boeing, Airbus and British Aerospace.

Conclusion: IAe started with the licensed manufacturing of a 24-passenger turboprop aircraft and subsequently a joint-venture design for a 44-passenger turboprop aircraft. In both it was moderately successful. IAe was able to manufacture these aircraft but was not able to receive certification from Western aviation authorities. Next, it embarked on a venture to develop, with substantial foreign engineering aid, a 64-68-passenger aircraft. Partly due to financial constraints and partly due to certification constraints it was not able to start series production and (internationally) sell the aircraft. Aside from limited market access due to certification, it is questionable whether IAe was able to produce the aircraft for a reasonable price. The claim of an Indonesian airline official who refused to lease CN-235 turboprops made by IPTN because the leasing company was asking such a high price that he could lease Boeing 737s for the same price illustrates the point. Aviation analysts also think that the stated $650 million for the development of the N-250 is more a product of creative accounting than a realistic assessment. The U.S. General Accounting Office estimated the total N-250 program cost at $1.2 billion. IAe also initiated design work on a 104/132-passenger jet-aircraft but because of financial constraints the work was stopped. Whether IAe has design capabilities for medium or large sized commercial aircraft still needs to be demonstrated, especially since it has relied much on foreign expertise.

3.3 AVIC (China)

The development of commercial aircraft in China started in the mid-1950s with small general purpose aircraft. The Antonov-2 (An-2), a 19-passenger piston aircraft was designed and developed in the Soviet Union. It was put into mass production as the Y-5. Similar general purpose aircraft have been produced since then, e.g. the Y-11 (9-10 seat) and the Y-12 (17 seats) turboprop aircraft. By the mid-1960s China had demand for domestic air transportation. This led to the approval of the Y-7 in 1966. The Y-7 is a licensed production of the 44-passenger turboprop An-24. Prototype production began in October 1969 and the first flight was on December 25th 1970. The Y-11, as a commercial aircraft, needed more emphasis on safety, economics, comfortability and operational life, and needed more ground and flight tests. The Chinese had difficulty carrying out all the development activities and getting the required certification for mass production. In July 1982 the Chinese government finally approved the design certification. However, all problems were not solved. Xian Aircraft Company (XAC) cooperated with Hong Kong Aircraft Engineering Company in 1985 to further improve the Y-7 and a certificate of airworthiness was awarded in January 1986 (Zijun, 1989).

The development of a short/medium range aircraft, the Y-8, was assigned to XAC in 1968. The Y-8 was a redesign of the An-12, a 14 passenger pressurized aircraft. Working with a design team of 570 people, it took over two years to finish the design. In December 1974 the first Y-8 was completed and the first flight followed two weeks later (Zijun, 1989).

The development of a large aircraft, the Y-10, was approved in 1973. The Y-10 is a ‘clumsy attempt to reverse-engineer the Boeing 707-300 (Flight International, 2001), a 150-passenger jet-aircraft. By June 1975 the design drawings were completed and prototype production began in the Shanghai Aircraft Factory (SAF). The first flight of the

Y-10 took place in September 1980. Two Y-10 prototypes were built but the development program was terminated because of market demand and cost (Zijun, 1989).
The next step towards large aircraft production was a co-production program between SAF and MDD. The agreement was for the assembly of 25 MD-82 aircraft kits. The program was later expanded to 35 aircraft. 15-20% of the airframe content was provided by Chinese industry. The MD-82 is a 170-passenger jet aircraft. The first flight of a SAF assembled MD-82 took place in July 1987 and delivery was in the same month (Zijun, 1989). Over an eight year period SAF assembled the 35 aircraft. The aircraft were of similar quality as MDD aircraft and five were sold to the US.
In 1993 Aviation Industries of China (AVIC) was founded which mapped out guidelines for the development of commercial aircraft. This involved domestic production, cooperation, and achievement of goals in three phases:

1. Co-production of the MD-90 with MDD to improve manufacturing capabilities.
2. Development of a 100-passenger aircraft by cooperating with another international company.
3. Domestic development and manufacturing of a 180-passenger aircraft (Zhongqiang, 1995)

The first phase was initiated in 1994 when AVIC signed an agreement with MDD to co-produce 20 MD-90-30, 190-passenger jet-aircraft. The first Chinese MD-90 was planned for completion in 1998 and the last by the end of 2000. The original agreement was for 150 aircraft with production to run through 2007 but this was scaled back to 40 aircraft of which 50-60% was to be Chinese manufactured. Because of immediate needs of Chinese airlines 20 of the aircraft were assembled in the US. In 1998 the program was halted. At that time, with no local buyers, no MD-90 aircraft had been assembled in China although enough parts were produced for the manufacture of three aircraft. Reasons why no airline was interested in the aircraft include that is was priced too high by AVIC.
Although the first phase was not completed, several attempts were made to initiate the second phase. A Memorandum of Understanding was reached in 1994 with South Korea to develop a civil aircraft but it did not materialize. In 1996 AIR and AVIC talked about the development of the AE-100, a completely new aircraft. After it was concluded that this was not feasible, the development of a derivative of an Airbus, the AE31X was discussed with Airbus but this also fell through as Airbus did not see a business case for the twinjet. Other unsuccessful attempts were made with Fokker and Boeing.
Next, the Chinese went back to phase 1, co-production of a Western aircraft. In 1997 ATR and China reached agreement on ATR-72 production sharing. Starting with the production of parts, the intention was to have a licensed production line in China. But, a complete production line has not been set up.
In 1999 AVIC was divided into AVIC I and AVIC II. AVIC I focuses on large- and medium-sized aircraft while AVIC II gives priority to feeder aircraft and helicopters. In 2001 AVIC I and Fairchild Dornier entered talks to examine the feasibility of producing the proposed 528JET in China but, partly due to the demise of Fairchild, the 528JET was never produced. In 2003 the Chinese conglomerate D'Long bought the 728 program. Plans are to continue final assembly in Germany but with up to 40% of the airframe manufactured in China. In 2002 AVIC I and Bombardier signed a tentative agreement to co-produce the CRJ-700/900 in Shanghai. By May 2003, the talks stalled. Simultaneously AVIC I was working on developing an indigenous aircraft. In 2002 AVIC I set up a

dedicated company to manage development of a Chinese 79 to 99 seat regional jet aircraft, the ARJ21. By 2004 work on the ARJ21 is progressing and AVIC I claims that it has sealed launch orders from three customers for 35 ARJ21 regional jets.
In 2002, a group of Dutch investors and Hogdu Aviation, a subsidiary of AVIC II, signed an agreement to revive Fokker 70/100 production by the end of 2003. So far no production has taken place. Also in 2002 AVIC II signed a joint venture agreement with Embraer for the production of the ERJ-145 aircraft. Harbin Embraer Aircraft industry can assemble up to two aircraft per month. In December 2003, the first Chinese-built ERJ-145 was completed but there was no customer for it.

Conclusion: AVIC (China) started with the licensed manufacturing of a 19-passenger piston aircraft and continued successfully with other small aircraft. It then made an attempt to develop and manufacture a 150-passenger jet-aircraft but this failed. AVIC then tried to develop large aircraft manufacturing expertise. This was only partly successful, i.e. the completed aircraft were certified by Western aviation authorities but they were only partly manufactured in China. A follow-on manufacturing program with higher Chinese content was unsuccessful due to the high production cost. Industry sources report that each of the 20 aircraft scheduled to be built and assembled in China were expected to cost approximately $10 million more than the corresponding aircraft built in the US. The high price is no surprise since assembly rates in the US for the MD-80 were about 139 per year in 1990 but the highest assembly rate in China was only 8 per year. Currently China is license producing a 50-passenger jet-aircraft but does not yet have customers. Whether China will find customers for the ERJ-145 remains to be seen. By 2002 Embraer already sold more than 650 ERJs internationally. Thus, a large market demand has already been filled and Embraer has reached a break-even point in manufacturing. With Brazilian production rates of 132 ERJ-145 per year and Chinese production rates of 24 aircraft per year it is likely that the Chinese production cost are uncompetitive. China is also working on the indigenous ARJ-21 jet-aircraft. It is questionable whether Chinese manufacturers can design a medium size aircraft when they haven't been able to completely manufacture a medium size aircraft. The two circumstances that favor the Chinese are a large domestic market and a government that seems intent on developing an aircraft manufacturing industry at all cost.

3.4 Embraer (Brazil)

The development of the Brazilian aircraft industry has been shaped by three ten-year plans spanning the period from 1950 to 1980. In the first ten-year period a government funded organization (CTA) sought to establish a teaching and training program to develop a support structure for the aviation industry. The second period required the establishment of technically strong local manufacturers. The third period was characterized as one of increasing sophistication of locally produced power plants, avionics, and aircraft systems that will go into Embraer products (Baranson, 1978).
Embraer was created in 1969 with the express purpose of promoting the development of the local aircraft industry. After six years of operation, it had three lines of aircraft in production: the EMB-110, a derivative of the French Nord 262, the EMB-201, a single-engine crop duster designed by Embraer, and the EMB-326GB, a jet trainer and ground attack aircraft produced under license from Aeronautica Macchi S.p.A., an Italian

corporation. By late 1974, Embraer employed 3500 people and had a total capitalization of about $20 million (Baranson, 1978).
In 1974, Brazil represented the largest single export market, outranking both Canada and Germany, for U.S. light aircraft (general aviation) manufacturers. U.S. manufacturers delivered 726 aircraft to Brazil in that year at a cost of $600 million. Severely pressed by this time with foreign exchange constraints and confident of its technical capabilities and sufficient internal market demand, Brazilian development authorities felt it was an appropriate moment for Embraer to begin a manufacturing program of light aircraft in close cooperation with a foreign aircraft manufacturer. Brazil sent a mission to the three major U.S. small aircraft producers, Piper, Beech and Cessna to solicit proposals on a production agreement. Each was told that Embraer desired to develop their own technical, managerial, manufacturing and marketing capabilities in small aircraft production and to reserve exclusively the domestic market thereafter for Brazilian-produced aircraft. As a result of negotiations, Piper was selected. Subsequently a technology transfer program was implemented. Production capability for the Piper models was transferred to Embraer in three phases, similar to Romanian and Indonesian experiences. In the first phase, completed structures such as fuselage, empennage, and wings were shipped to Embraer for final assembly. In the second phase, Embraer received structured sub-assemblies for mating in jigs in addition to the functions of the first phase. In the third phase, Piper initially sent component parts for assembly by Embraer. Subsequently Brazilian content of parts was increased (Baranson, 1978).
In 1985 the EMB-120, a 30-seat turboprop aircraft derived from the EMB-110 was launched. It received FAA (1985) and European certification (1986). To design and produce this new aircraft, considerable investment were made in several manufacturing skills. The EMB-120 was quite successful and captured a third of the total market for 30-40 seat commuters. In 1989 Embraer decided to venture into what was then a niche market for regional jets by developing the ERJ-145, a 50-passenger jet-aircraft. In the 1994 Embraer was privatized. During the search for new owners, the ERJ-145 project was stopped but after the privatization it accelerated. The ERJ-145 development effort came at the right time. The market for regional jets was growing rapidly, e.g. by more than 50% between 1998 and 1999. In 1996 the ERJ-145 was introduced and in the same year it received FAA certification JAA followed in 1997. It was a successful product and as a result, Embraer returned to profitability in 1998 after 11 consecutive years in the red (Goldstein, 2001). In 1997 Embraer announced a smaller derivative of the ERJ-145, the ERJ-135, a 37-passenger jet. In 1999 Embraer announced that it would develop a new 70-108 seat jet-aircraft family; the ERJ170/190 program. Embraer budgeted $600 million to develop the ERJ170 and $150 million more for the ERJ190. It wants risk-sharing partners to fund one third. At later points, the development costs for the ERJ170/190 were revised to an estimated $850. In 2000 another derivative of the ERJ-145, the ERJ-140, a 44-passenger jet was announced.
Since 1998 Embraer has been profitable each year although since 2001 profit has been declining. Also, in 1999 Brazil was told by the WTO that it had to stop providing illegal export subsidies in support of regional jet sales. Brazil's PROEX program was providing up to a 3.5% reduction in interest rates on loans to purchasers of exported Brazilian aircraft.

Conclusion: Embraer started successfully with the licensed manufacturing of a small aircraft while stressing design knowledge. Initially building on its domestic market Embraer has designed aircraft of increasing size. Embraer's most recent products have all been recognized by Western aviation authorities. Despite continuous losses in the 1980s and for a large part of the 1990s Embraer survived with government support. Since 1994 Embraer was privatized. Since 1998 is has been profitable. However, in recent years Brazil has been told by the WTO to halt (illegally) subsidizing aircraft exports and since 2001 profits have been declining. Whether Embraer will be able to survive a long-term downturn while it has been heavily investing in a new aircraft family remains a question.

8 Conclusion

All four companies entered the aircraft industry by building up aircraft manufacturing expertise through licensed production of small aircraft. Romaero and AVIC next focused on acquiring manufacturing capabilities for large aircraft. They were both partly successful, i.e. their products were recognized by Western aviation authorities but only partly domestically manufactured. Financial constraints caused Romaero to end aircraft manufacturing. AVIC initiated another large jet license production program but this was terminated for cost reasons. AVIC made several attempts to jointly develop an aircraft with a Western manufacturer but none of these materialized. Subsequently AVIC continued building up aircraft manufacturing expertise by producing ERJ-145 aircraft. It is currently, with Western engineering aid, designing the ARJ21. AVIC has received continued Chinese government support over the years. This has allowed it to remain in the industry.

IAe and Embraer, following their small aircraft manufacturing experience, focused on acquiring aircraft design capabilities. IAe jointly developed a small aircraft and subsequently developed its own medium size aircraft although with substantial western help. IAe aircraft were not certified by Western authorities and consequently its sales limited. IAe also started the development of a jet-aircraft. Without financial Indonesian government aid due to IMF imposed economic constraints IAe has been mainly struggling to survive. Embraer, with a heavy emphasis on increasing design knowledge, continued to indigenously design and develop aircraft. It has slowly built up the size of the aircraft it is developing and manufacturing. Its aircraft have been certified by Western aviation authorities which is a clear signal that Embraer has acquired sufficient aircraft design, development and manufacturing skills. Before 1994 Embraer was heavily supported by the Brazilian government which helped it survive many years of loss making. Since then, it has become privatized. While regional sales have been up, Embraer has been profitable but whether Embraer can survive long-term without its financial government aid is still an open question.

The cases show that being able to produce a small turboprop aircraft does not automatically mean that one can manufacture a large jet-aircraft. Apparently this requires different skills. Having manufacturing capabilities also does not mean that one is capable of designing an aircraft. These large aircraft manufacturing and design skills have to be developed over a length of time. A large domestic market and government backing provides companies with circumstances to grow. However, to be able to sell internationally, the companies need Western aviation authorities to certify the aircraft.

This is affected by the national aviation authorities standing as the Indonesian example shows. Also, manufacturing skills alone are not sufficient to survive in this industry. One of the key criteria is cost competitiveness. This is a particularly tricky issue since it relates to economies of scale. Not having access to foreign markets, e.g. through non-certification or production of old aircraft, is therefore detrimental to survival. Less experienced companies are also at a disadvantage because lower production rates affect the speed with which they go down their learning curve and therefore their operating cost. Any time licensed aircraft production is undertaken the licensee is therefore at a competitive disadvantage. The cases show that aircraft licensing programs often involve aircraft at the end of their life cycles. This is also detrimental to the licensee's ability to export the aircraft. The way to circumvent this, i.e. manufacturing indigenously designed aircraft, is extremely challenging because companies need to build up design and manufacturing experience. As long as companies or governments have enough financial resources, it may buy them time to build up critical skills. However, as the cases show, global financial institutions may not allow this for a long time period. Developing countries are therefore in a very difficult situation if they want to build up an aircraft manufacturing industry.

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