Retrospective Analysis of the AM-X Aircraft Acquisition Program (1982-1994) and the implications for the Technological Path of the Brazilian Aeronautical Industry Leader

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OBJECTIVE OF THE PAPER

• To show the importance of the AM-X Acquisition Program for the technological development of EMBRAER, Brazil’s leading aeronautical company;

• To identify the technological outcomes of this military program on EMBRAER;

• Contribute to evaluate a military acquisition program of development of technological capabilities;
  – Programs involve phases of development and manufacturing an aircraft in Brazil.
• Which technological capabilities were developed by EMBRAER in the AM-X Program?
AMX AIRCRAFT (A-1)

GROUND-ATTACK AIRCRAFT
The AM-X ACQUISITION PROGRAM

• In 1980: Program underway in Italy (Italian version and Brazilian version);

• The technical cooperation between Italy and Brazil included knowledge transfer, exchange of experiences and material support;

• Equipment and material would have waiver of import permit and exemption of import taxes and fees.
The AM-X ACQUISITION PROGRAM

• Main objective of the Brazilian Air Force: Empowering the development of the Brazilian aeronautical industry;

- In order to achieve it, the Brazilian government created The National Program for Technological Capabilities targeting selected companies.

• 1994: it was privatized;

• With customers all over the world and important internationally partners;

• Business units: Commercial Aviation, Executive Aviation and Defense & Security.
AM-X => allowed the company to reach higher technological and industrial levels. It resulted in the development of commercially and technologically successful jets, such as the **ERJ 145** and the **E-Jets 170 and 190** (both for **commercial aviation**).
HYPOTHESES

1. The AM-X Program provided the basis to build important technological capabilities in EMBRAER;

2. EMBRAER´s technological path is related to the Brazilian defense programs.

3. The spinoffs generated during a defense program are responsible for the creation of new technological capabilities that are relevant to the technological progress of Brazilian aeronautical industry.
MOTIVATION

• Few studies have analyzed the outcomes from the participation in large governmental programs, especially in aerospace sector;

• There is a demand for identification the outcomes of the defense program. The policy makers and the society need to know the real gains of these programs.
RESEARCH DESIGN AND METHOD

• Historical perspective to sharpen our understanding of the phenomenon of interest as it unfolded over time (Kieser, 1994);

• Qualitative research: study case;

• Sources:
  ❖ **Field research:**
    ❖ Open interviews with the Manager of the AM-X Program and his team;
    ❖ A documentary survey: to analyze the Memorandum of Understanding between Brazil and Italy, the main contracts, other regulations and documents available in COPAC (*the executive body of aircraft purchases in Brazilian Air Force*);

⇒ The general program guidelines and the evidence of its importance for the development of the Brazilian aeronautical industry;

❖ **Technological studies:** to identify the technical areas that were improved by the participation in the AM-X Program (Cabral, 1987; Frischtak, 1994; Oliveira, 2005, Marques, 2011).
THE FRAMEWORK

• Literature about the evaluation of technological investment programs: Bureau d'Economie et théorique Appliquée (BETA) (BACH, 1992);

• Direct effects: defined in the contracts;

• Indirect effects: the spinoffs
  - unpredicted products, new technologies, organizational changes, new methods, new techniques, new technological capabilities, etc;

• The spinoffs are a broader phenomenon than the process of technological transfer and can generate an economic impact as important or even more important than the expected innovation (BACH, 1992);

• The Spinoffs are the result of the learning process, which is derived from the sedimentation of organizations’ technological capabilities (FURTADO et al, 2008).
How did the program work?

### Table 1. Percentage of EMBRAER Production

<table>
<thead>
<tr>
<th>EMBRAER</th>
<th>WINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wings</td>
<td>16,8%</td>
</tr>
<tr>
<td>Air intakes</td>
<td>1,0%</td>
</tr>
<tr>
<td>Slats</td>
<td>1,6%</td>
</tr>
<tr>
<td>Flaps</td>
<td>2,3%</td>
</tr>
<tr>
<td>4 Pylons</td>
<td>3,7%</td>
</tr>
<tr>
<td>4 sublaries tanks</td>
<td>4,3%</td>
</tr>
<tr>
<td>Total</td>
<td>29,7%</td>
</tr>
</tbody>
</table>

Source: Prepared from the Memorandum of Understanding between Brazil and Italy.

### Table 2. Percentage of AERITALIA Production

<table>
<thead>
<tr>
<th>AERITALIA/ALENIA</th>
<th>CENTRAL FUSELAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front fuselage</td>
<td>8,8%</td>
</tr>
<tr>
<td>Central fuselage</td>
<td>28,2%</td>
</tr>
<tr>
<td>Ailerons</td>
<td>0,8%</td>
</tr>
<tr>
<td>Spoilers</td>
<td>1,35%</td>
</tr>
<tr>
<td>Horizontal stabilizer</td>
<td>3,3%</td>
</tr>
<tr>
<td>Vertical stabilizer</td>
<td>2,5%</td>
</tr>
<tr>
<td>Twin carriers</td>
<td>1,6%</td>
</tr>
<tr>
<td>Total</td>
<td>46,5%</td>
</tr>
</tbody>
</table>

Source: Prepared from the Memorandum of Understanding between Brazil and Italy.

### Table 3. Percentage of AERMACCHI Production

<table>
<thead>
<tr>
<th>AERMACCHI</th>
<th>UPPER FUSELAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Fuselage</td>
<td>19,5%</td>
</tr>
<tr>
<td>Lower Fuselage</td>
<td>4,3%</td>
</tr>
<tr>
<td>Total</td>
<td>23,8%</td>
</tr>
</tbody>
</table>

Source: Prepared from the Memorandum of Understanding between Brazil and Italy.

Brazil (29.7%)

Italy (70.3%)

Exchange of the labor force between the two countries.
How did the program work?

FOR ENGINE MANUFACTURING:

• Industrial Cooperation Agreement (1986) to develop Celma capabilities in engine;

• Rolls Royce, Fiat Aviazione, Alfa Romeo Avio, Rinaldo Piaggio and Celma.

CONTRACTS:

- The Joint Contracts => joint activities with joint funding;
- The National Contracts => non-common activities.

• The principle of single-source supplying: only one industry was responsible for providing materials and equipment for both countries.
• EMBRAER was responsible for managing its own growth and the growth of industrial capability of selected Brazilian companies within the aeronautical industry;

• The “package” of capability:
  ❖ Training activities of technical staff,
  ❖ Purchase of machinery,
  ❖ Production equipment,
  ❖ Testing equipment,
  ❖ Laboratory,
  ❖ Special tools,
  ❖ Technology services,
  ❖ Technical assistance and
  ❖ Specific training for the industrialization of the landing gear and hydraulic equipments.
### NATIONAL CAPABILITY PLAN:

<table>
<thead>
<tr>
<th>Phases</th>
<th>Dates</th>
<th>Activities</th>
<th>Connection Activities</th>
<th>Company</th>
<th>Country</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition, Development and Production</strong></td>
<td>1981 e 1986.</td>
<td>Planning to execution. Activities of production and development.</td>
<td>Purchase of equipment and training necessary for industrialization of the landing gear.</td>
<td>EMBRAER</td>
<td>Italy and Brazil.</td>
<td>Remains in operation.</td>
</tr>
<tr>
<td><strong>Industrialization</strong></td>
<td>1987 e 1988.</td>
<td>Electronic equipment production.</td>
<td>Acquisition of licenses and technical information, training and technical assistance.</td>
<td>ABC Sistemas</td>
<td>Brazil.</td>
<td>No information.</td>
</tr>
</tbody>
</table>

Source: Elaborated from the Memorandum of Understanding between Brazil and Italy.
TECHNOLOGICAL EVOLUTION OF EMBRAER FROM THE AM-X PROGRAM

• Eight key technology areas were analyzed: aerodynamics, structures, materials, product engineering, avionics, flight control, flight tests (all of them in the Technical Department) and manufacturing (Production Department);

• These areas were representative of the majority of the technological efforts made by Embraer in its earlier years.

Cabral (1987)
THE MAIN TECHNOLOGICAL LEAPS ARISING FROM THE AM-X PROGRAM

- Manufacturing
- Avionics
- Product Engineering
# THE MAIN TECHNOLOGICAL LEAPS

## THE MAIN RESULTS

<table>
<thead>
<tr>
<th>Technical Areas</th>
<th>Subtechnical Area</th>
<th>Technical Spinoffs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting of sheet metal</td>
<td>Router Trumpf: digitally controled, best arrangement of the different parts for cutting the whole plate.</td>
<td></td>
</tr>
<tr>
<td>parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing of machined parts</td>
<td>Grantry´s with five axles programmed by CAD-CAM, complex shapes and reduce tolerances.</td>
<td></td>
</tr>
<tr>
<td>Production of composite material</td>
<td>Manual impregnation to the use of a vacuum system.</td>
<td></td>
</tr>
<tr>
<td>Metalworking</td>
<td>Operation of nonstructural welders.</td>
<td></td>
</tr>
<tr>
<td>Bonding</td>
<td>Structural bonding applied to flap.</td>
<td></td>
</tr>
<tr>
<td>Assembly</td>
<td>Line format to the &quot;U&quot; format, with suport teams on both sides. Final assembly by system to assemble final by station.</td>
<td></td>
</tr>
<tr>
<td>Quality control</td>
<td>Sophistiticated digitally controlled machines and new computers for inspection. Directed of Quality Assurance was created.</td>
<td></td>
</tr>
<tr>
<td>Production Department</td>
<td>In 1979: 7 engineers =&gt; In 1986: 73 engineers.</td>
<td></td>
</tr>
</tbody>
</table>

THE MAIN TECHNOLOGICAL LEAPS

The great evolution occurred through the introduction of 5-axis machining process (CNC - Computer Numerically Controlled Machine Tool):

- Amount of human intervention reduced;
- Better surface finish;
- More complex parts can be manufactured;

Programmed by CAM (Computer Aided Manufacturing)

Production Department Growth:
In 1979: 7 engineers => In 1986: 73 engineers.
## THE MAIN TECHNOLOGICAL LEAPS

<table>
<thead>
<tr>
<th>Technical Areas</th>
<th>Technical Spinoffs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AVIONICS</strong></td>
<td>Digital transmission system: revolution on the instruments on board. The company was a copier of imported technology and adapter/modifier for different ends. Brasilia: 10 engineers =&gt; AM-X: 60 engineers (trained in Italy and worked directly in program).</td>
</tr>
<tr>
<td><strong>PRODUCT ENGINEERING</strong></td>
<td>CAD-CAM (before clipboards, tracing paper, drawing boards and glass tables for photo tracing). The company was a provider of original design in the same operational and market area; an adapter and copier of imported technology.</td>
</tr>
<tr>
<td><strong>AERODYNAMICS</strong></td>
<td>NACA/NASA public domain profiles =&gt; own profiles in the development phase. Aerodynamics coefficients calculated by wind-tunel and flight tests.</td>
</tr>
<tr>
<td><strong>MATERIALS</strong></td>
<td>Alclad plates with autoclave curing at 180°.</td>
</tr>
<tr>
<td><strong>FLIGHT CONTROLS</strong></td>
<td>Fly-by-Wire system.</td>
</tr>
<tr>
<td><strong>FLIGHT TESTS</strong></td>
<td>AM-X aircraft needed sophisticated tests (inertial navigation system with accuracy check and photographic reconnaissance system), flight quality tests (stability and control) and performance with dynamic maneuvers (calculation of aerodynamic parameters in flight maneuvers) =&gt; high specialization of labor.</td>
</tr>
</tbody>
</table>

THE MAIN TECHNOLOGICAL LEAPS

Avionics: Digital transmission system => caused revolution on instruments on board.

Brasilia: 10 engineers => AM-X: 60 engineers (trained in Italy and worked directly in program).

Product Engineering: CAD-CAM (Computer-Aided Design and Computer Aided Manufacturing) => caused a revolution on design and simulating manufacturing conditions.
TECHNOLOGICAL LEAPS

AM-X Program (1982-1995)

DESIGN
- Product engineering (CAD-CAM);
- Aerodynamics (own profiles in the development phase);
- Structures (structural analysis);
- Avionics and Flight Commands (international frontier);

MANUFACTURING
- Process (5-axis machining process, production knowledge in tooling and parts, quality control);
- Assembly ("U" format with support teams on both sides and assembly final by station).

Source: Own formulation from Cabral, 1987; Frischtak, 1994; and Marques, 2011.
CONCLUSION

• The Program emphasized the new processes that EMBRAER has come to master, especially in manufacturing aero-structures, avionics integration and product engineering.

• It resulted in production capabilities and innovation capabilities, especially in the design of new aircrafts and new technologies;

• The AM-X program was not a program for importation of technology but a technological modernization program involving local efforts to develop new technological knowledge.
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CENTRAL ARCHIVES OF COPAC

Brazilian Air Force A-1M

43 aircrafts
18 received by Embraer for the modernization.

The Brazilian Government through the Air Force remain an important source of demand. For 20 more years of operation.
Thank you!

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