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

Josiane de Araújo Francelino
Supervisor: Prof. PhD Ligia Maria Soto Urbina
Co-Supervisor: Prof. PhD André Tosi Furtado (UNICAMP)

Aeronautics Institute of Technology (ITA)

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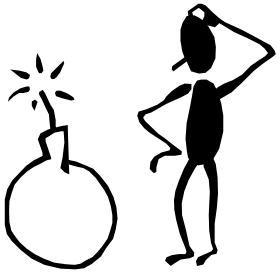
OBJECTIVE OF THE PAPER

- 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.

RESEARCH QUESTION



- Which technological capabilities were developed by EMBRAER in the AM-X Program?

AMX AIRCRAFT (A-1)

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 Bazilian Air Force**:

Empowering the development of the Brazilian aeronautical industry;

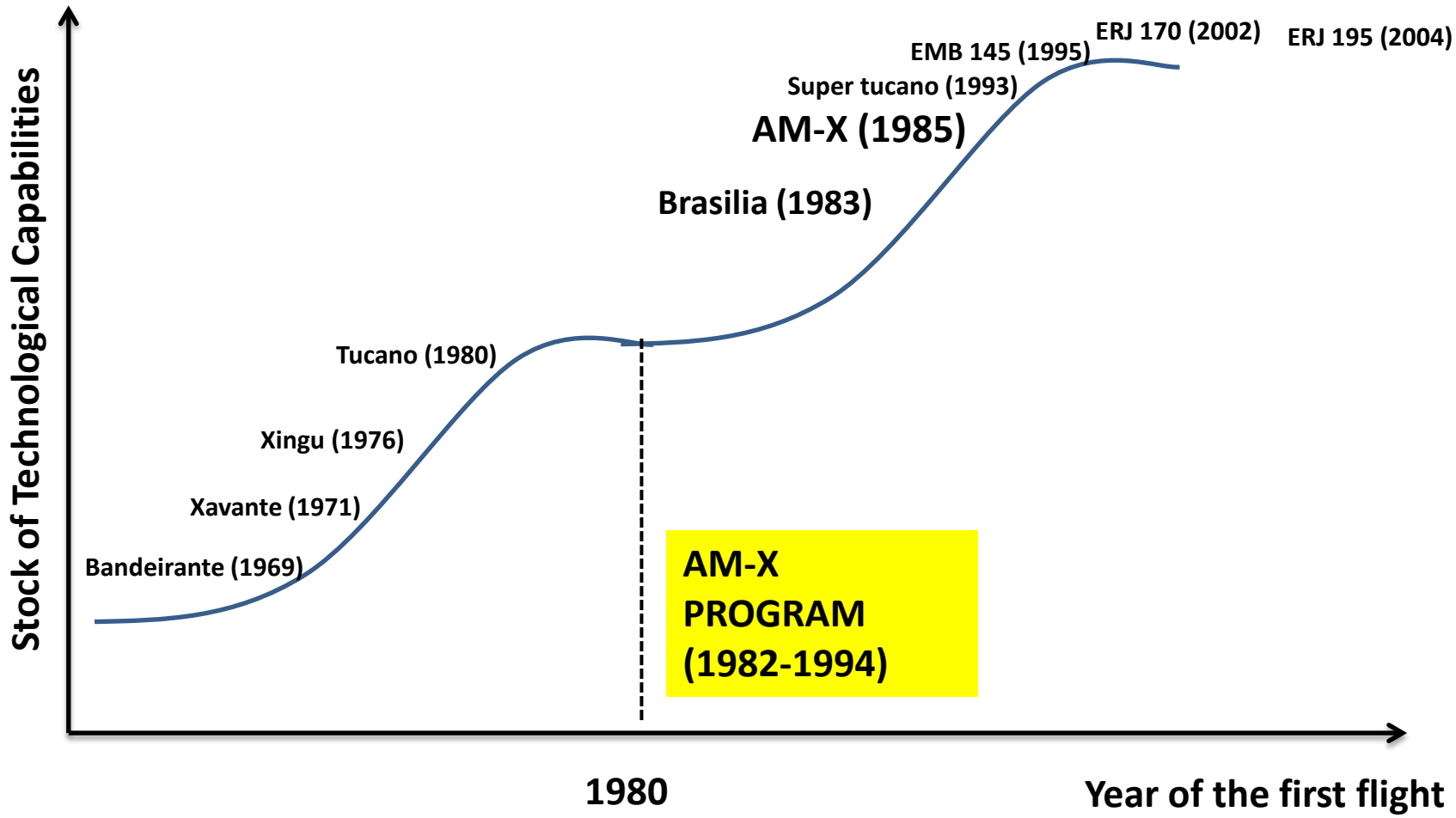
❖ In order to achieve it, the Brazilian government created The National Program for Technological Capabilities targeting selected companies.

EMBRAER

- Created on 1969: State owned company (1969-1994)
- 1994: it was privatized;
- With customers all over the world and **important internationally partners**;
- Business units: Commercial Aviation, Executive Aviation and Defense & Security.

EMBRAER´S TECHNOLOGICAL PATH THROUGH ITS AIRCRAFT MODELS

AM-X => **<u>allowed the company to reach higher technological and industrial levels.</u>** 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)**.



Source: Own formulation from Cabral, 1987; Frischtak, 1994; Oliveira, 2005; Marques, 2011; and *EMBRAER Timeline, 2014;*

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.

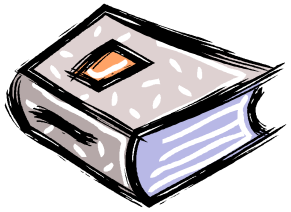
RESEARCH DESIGN AND METHOD

- **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 Apliquée (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?

Brazil (29.7%)

Table 1. Percentage of EMBRAER Production

EMBRAER	WINGS
Wings	16,8%
Air intakes	1,0%
Slats	1,6%
Flaps	2,3%
4 Pylons	3,7%
4 sublares tanks	4,3%
Total	29,7%

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

Italy (70.3%)

Table 2. Percentage of AERITALIA Production

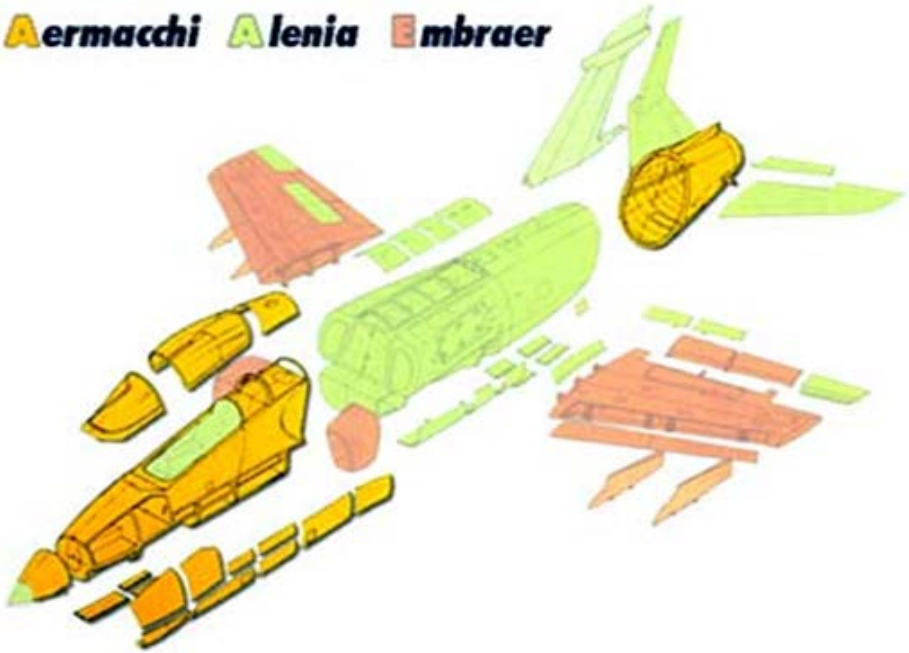
AERITALIA/ALENIA	CENTRAL FUSELAGE
Front fuselage	8,8%
Central fuselage	28,2%
Ailerons	0,8%
Spoilers	1,35%
Horizontal stabilizer	3,3%
Vertical stabilizer	2,5%
Twin carriers	1,6%
Total	46,5%

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

Table 3. Percentage of AERMACCHI Production

AERMACCHI	UPPER FUSELAGE
Upper Fuselage	19,5%
Lower Fuselage	4,3%
Total	23,8%

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



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.

NATIONAL CAPABILITY PLAN:

- 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:

Supplementary Capability Program, Key Activities and Companies Involved

Phases	Dates	Activities	Connection Activities	Company	Country	Observation
Definition, Development and Production	1981 e 1986.	Planning to execution. Activities of production and development.	Purchase of equipment and training necessary for industrialization of the landing gear.	EMBRAER	Italy and Brazil.	Remains in operation.
Development and Production	1984; 1985; 1989 e 1991.	Industrialization and production of the engine.	Acquisition of the license for the engine. Fiat was contracted for the Celma training.	Celma	Brazil.	Remains in operation.
Industrialization	1987; 1989 e 1991.	Production of avionics components.	Acquisition of licenses and technical information, training and technical assistance.	Aeroeletronica	Brazil.	Remains in operation.
Industrialization	1987 e 1988.	Electronic equipment production.	Acquisition of licenses and technical information, training and technical assistance.	ABC Sistemas	Brazil.	No information.
Industrialization	1988.	Electronic equipment production.		Elebra Telecom	Brazil.	Went bankrupt.
Industrialization	1986; 1987; 1988; 1991 e 1993.	Production Radar.	Contracts of industrialization, development and production.	Tecnasa	Brazil.	No information.
Industrialization	1986 e 1988.		Tranfer of technology from Rockwell Collins.	Engesa	Brazil.	Went bankrupt.

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		
Technical Areas	**Subtechnical Area**	**Technical Spinoffs**
MANUFACTURING	Cutting of sheet metal parts	Router Trumpf: digitally controled, best arrangement of the different parts for cutting the whole plate.
	Manufacturing of machined parts	Grantry´s with five axles programmed by CAD-CAM, complex shapes and reduce tolerances.
	Production of composite material	Manual impregnation to the use of a vacuum system.
	Metalworking	Operation of nonstructural welders.
	Bonding	Structural bonding applied to flap.
	Assembly	Line format to the "U" format, with suport teams on both sides. Final assembly by system to assemby final by station.
	Quality control	Sophistiticated digitally controlled machines and new computers for inspection. Directored of Quality Assurance was created.
	Production Department	In 1979: 7 engineers => In 1986: 73 engineers.
Source: Cabral, 1987.		

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

THE MAIN RESULTS	
Technical Areas	**Technical Spinoffs**
AVIONICS	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 => AM-X: 60 engineers (trained in Italy and worked directly in program).
PRODUCT ENGINEERING	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.
AERODYNAMICS	NACA/NASA public domain proflies => own profiles in the development phase. Aerodynamics coeficients calculated by wind-tunel and flight tests.
MATERIALS	Alclad plates with autoclave curing at 180°.
FLIGHT CONTROLS	Fly-by-Wire system.
FLIGHT TESTS	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) => high specialization of labor.
Source: Cabral, 1987.	

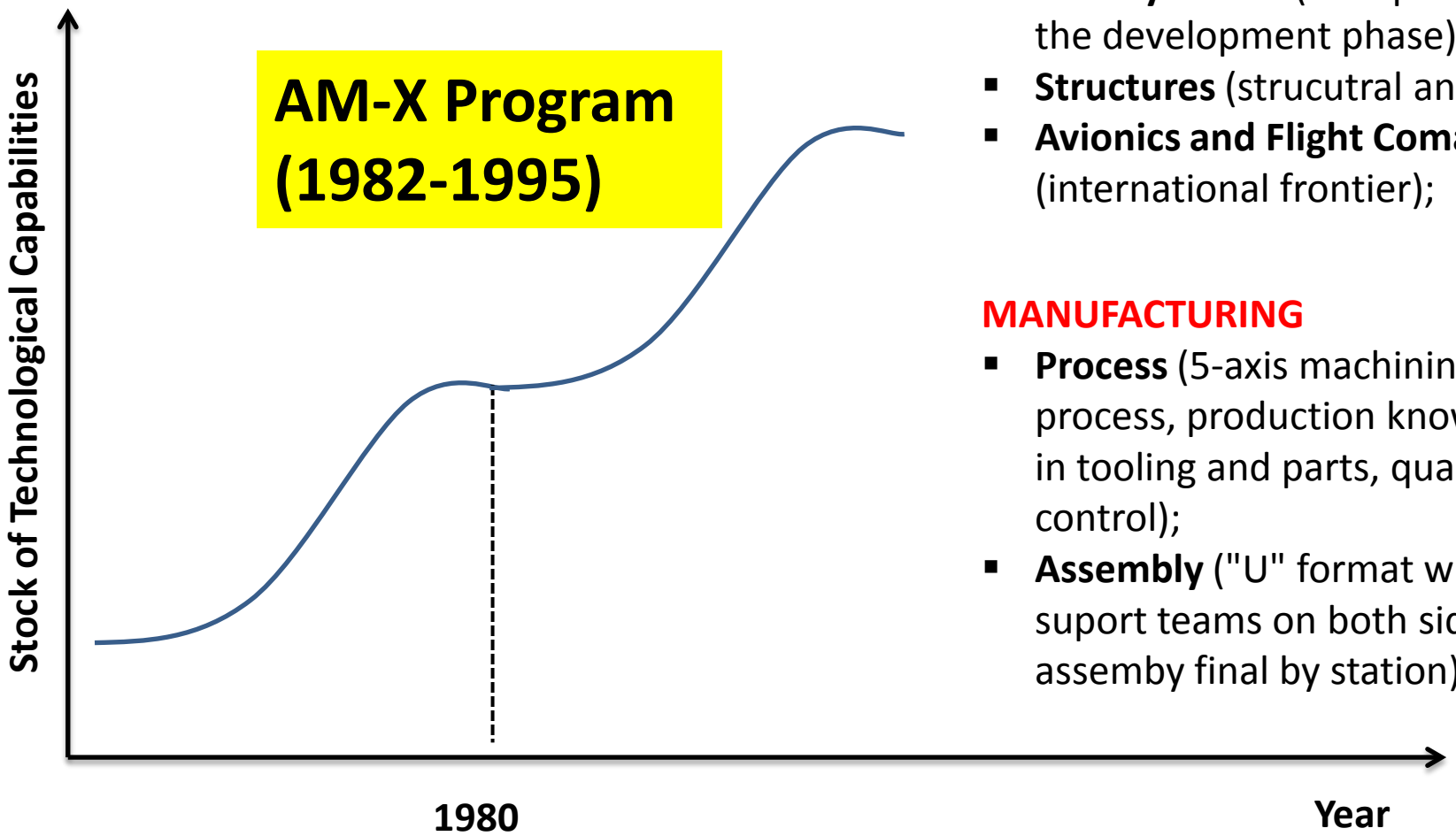
THE MAIN TECHNOLOGICAL LEAPS

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



DESIGN

- **Product engineering** (CAD-CAM);
- **Aerodynamics** (own profiles in the development phase);
- **Structures** (strucutral analysis);
- **Avionics and Flight Comands** (international frontier);

MANUFACTURING

- **Process** (5-axis machining process, production knowledge in tooling and parts, quality control);
- **Assembly** ("U" format with suport teams on both sides and assemby 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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STATUS:

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!

Josiane de Araújo Francelino (From Brazil)
josifrancelino@yahoo.com.br