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ANALYSIS OF GEOMETRIC AND FLYING CHARACTERISTICS OF SANTOS-DUMONT'S 14-BIS

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Abstract. *On November 12th 1906, Brazilian inventor Alberto Santos-Dumont flew a distance of 220 meters in 22 seconds with his 14-Bis at Bagatelle Field in France. He was the first to officially prove to the world that manned powered flight was possible for heavier than air machines. With that flight he also set the first aviation record and won the Aéro-Club de France Prize, given to the first manned airplane to take off and fly a minimum distance of 100 meters by its own means. This paper describes some of the geometric and flying characteristics of Santos-Dumont's 14-Bis. Determination of those characteristics are based on a historical review and on first order theoretical evaluations. Unfortunately most of the relevant information about the airplane was lost or never properly recorded. A great effort was made to consider and weigh all available information about the 14-Bis, but the obtained results and conclusions are certainly not final.*

keywords: *Santos-Dumont, 14-Bis, Geometric characteristics, Flight characteristics*

1. Introduction

Alberto Santos-Dumont was born on July 20th 1873 in Brazil. In 1892 he went to Paris, France, to advance his studies on engineering (Villares, 1953). He had always been attracted to machines and, when he learned about lighter-than-air vehicles, he immediately tried to arrange a flight. High costs discouraged him until he met Mr. Lachambre who asked 250 Francs for a four hour flight. After that flight, Santos-Dumont started his aeronautical career constructing and flying balloons. On 4 July 1898 his first balloon, named Brasil, took flight in the skies of the French capital. The spherical balloon, filled with Hydrogen, had mere 113 m^3 (diameter of 6 meters) but was able to lift Santos-Dumont who weighted only 50 kg. He innovated balloon design by using Japanese silk for the envelope, much lighter than other materials used at that time. Balloon makers expressed concern about the stability of such small craft but that was adjusted by extending the basket suspension cables thus lowering the center of gravity. He made several flights with Brasil and built two other balloons: the Amérique and the Deux Amériques.

When Santos-Dumont started his plans to use an internal combustion engine to propel an Hydrogen filled dirigible people tried to discourage him. The obvious concern was that sparks could ignite the highly flammable gas. That did not stop him and the history of success of his dirigibles proved he was right. That gave him an advantage in terms of power to weight ratio when compared to steam or electric propulsion (energy source included). Between 1898 and 1901 he built five different dirigibles naming them No.1 to No.5. Santos-Dumont made several flights always attracting much attention and giving him great popularity in France.

In 1898 the Aéro-Club de France was founded and, in 1900, organized the first dirigible competition which was named the Grand Prix Deutsch de La Meurthe. The one hundred thousand Franc prize was to be given to the first dirigible which, starting from Saint-Cloud, went around the Eiffel Tower and back to the starting point in less than 30 minutes. Many competitors were attracted by the prize including Roze, Firmin Bousson, Smitter, the Lebaudy brothers, Bradsky and, another Brazilian, Augusto Severo. Santos-Dumont knew his dirigibles could complete the established course but their speed was not high enough. He then built No.6 with length of 33 meters, diameter of 6 meters and a Buchet 20 HP internal combustion engine. On October 19th 1901, Santos-Dumont won the Grand Prix Deutsch de La Meurthe with No.6 and his popularity spread throughout Europe and the Americas. He gave half of the prize to his assistants and half to poor people in Paris.

He continued his experiments with dirigible No.7, which was intended to exceed 80 km/h speed. In June 1904 the aircraft was sent to Saint Louis to participate in a race during the World Fair. Upon arrival the dirigible envelope was found ripped apart as if it had been cut by a knife. Very expensive, it was never rebuilt. Dirigible No.9 was built to serve as a personal transport (he skipped No.8 due to superstition). Very small, 12 meters in length, 5 meters in height, it could land on small spaces and became known as the flying chariot. Dirigible No.10 was designed as a transport for up to 20 passengers but flew only a few times, always arrested by cables, and was abandoned.

Practical research on airplanes started in the beginning of the 19th Century. George Cayley conducted experiments with gliders in 1804 and was followed by the Le Bris, in 1857, by Mouliard, in 1865, then by Otto and Gustav Lilienthal, between 1891 and 1896, and by Octave Chanute. Motorized airplanes had already been tested by Stringfellow around 1857 but without success. Samuel Langley built several motorized airplane models which made very successful flights. In 1903 he tried to fly a platform launched manned airplane without success. Before that, others had already tried to fly manned powered heavier than air machines, most notably Hiram Maxim who conducted experiments with a steam powered airplane running on tracks. Clement Ader was financed by the French Government to build the Eóle in 1890. Although Ader claimed to be the first to fly an airplane, official reports of the time do not sustain his claim.

The Wright brothers had been developing gliders since 1899 when, in 1903, they started to fly a motorized version of their No.3 glider. They did not wish to publicize their achievements however and, although some news spread throughout America and Europe, they were not confirmed until late in 1908. At that time the Wright brothers performed public flights in Europe for the first time and set several aviation world records.

Santos-Dumont was also very interested in heavier than air aircraft and, by the end of 1904, he started to explore the possibility of powered flight. He designed a monoplane, No.11, for which he did not find a suitable engine. He also built the prototype of an helicopter, No.12, with two large propellers powered by a 24 HP, eight cylinder engine. He never tried to make it fly. His next balloon, No.13, combined hot air and Hydrogen for aerostatic lift. It was destroyed during a storm before it could be tested. In the beginning of 1905 he designed and built dirigible No.14 as a fast, highly maneuverable aircraft.

2. The 14-Bis

To motivate further advances in aeronautics the Aéro-Club de France instituted, in the end of 1905, a 1,500 Franc prize for the first aeronaut to accomplish a 100 meter long flight on an airplane taking-off, by its own means, from level ground (a maximum 10% slope). At the same time Ernest Archdeacon, club president, offered 3,000 Franc for a 25 meter long flight. Captain Ferber, of the French Army, was experimenting with gliders and kept contact with Chanute and the Wright brothers. Louis Blériot got associated with Gabriel Voisin to build an airplane based on the Voisin-Archdeacon glider. At that time Santos-Dumont recognized that the Antoinette type engines, developed by Levasseur for racing boats, were light and powerful enough to be used in aviation. He and his assistants then started to work on a biplane aircraft based on Hargrave's box kites (Fig. 1) and powered by a Levasseur engine. Lawrence Hargrave's work with box kites was well known and respected in Europe. The large lift generation capacity of his kite designs is probably what made Santos-Dumont choose that configuration.

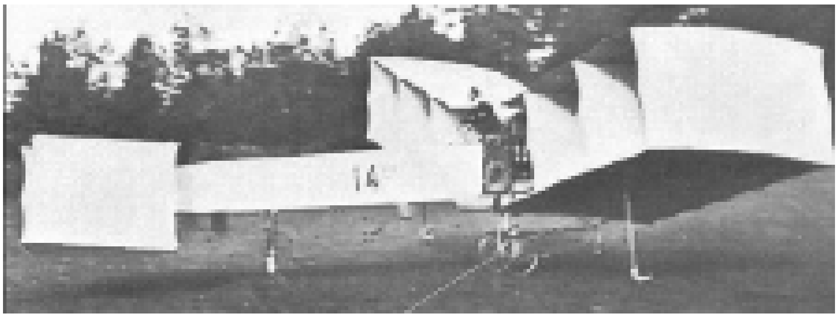

Figure 1: A side view of the 14-Bis.

The aircraft, made of bamboo poles and silk covering, with aluminum fixtures, was powered by a single 24 HP Antoinette engine. The engine, placed at the airplane rear end, drove a two blade, paddle type propeller in a pusher configuration (Fig. 2).

The pilot was placed standing up in a balloon type basket located in front of the engine strut. Longitudinal control was effected through a lever and directional control through a wheel. Landing gear was composed of two bicycle wheels attached to the engine strut. A third small wheel was placed behind the main gear but was removed, later on, during development of the aircraft. A front pole, placed under the fuselage, gave longitudinal support and two side poles, placed under the wings, gave lateral stability while on the ground.

Each wing was composed of three Hargrave's cells and were attached to the engine support with a dihedral angle. A single box kite cell was placed at the aircraft nose to provide pitch and yaw control. The engine strut and canard were connected by a silk covered, square section fuselage. According to Napoleão, 1988, the inventor chose the canard configuration to avoid lift reduction during take-off. Gibbs-Smith, 1985, mentions that the canard configuration was

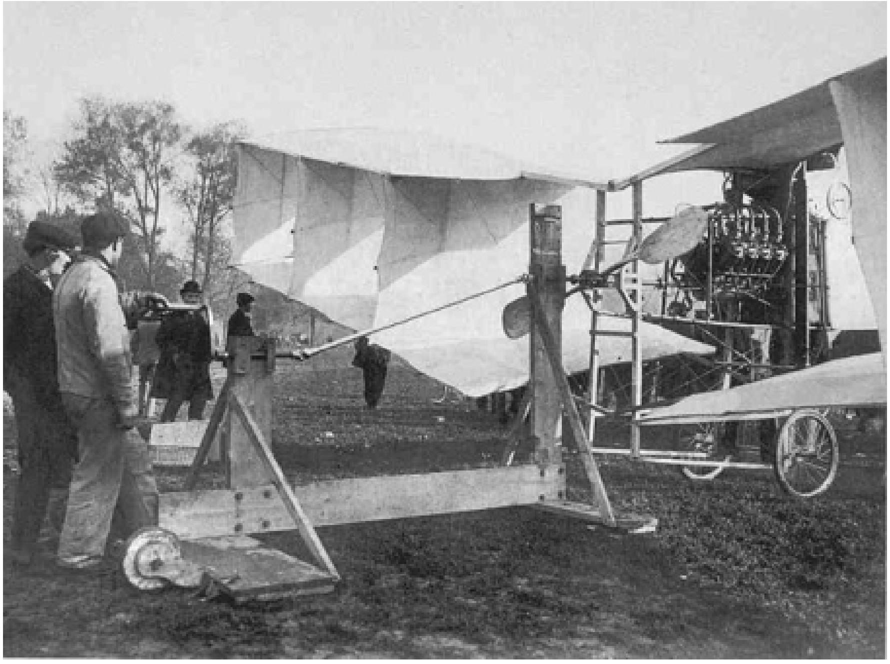

Figure 2: Engine starting mechanism (Musa *et al.*, 2001).

chosen (and that applies to the Wright brothers too) to avoid nose down tendencies presented by Lilienthal's gliders. Approximate airplane dimensions were: length of 10 meters. wing span of 12 meters, wing chord of 2.5 meters. The canard had a span of 2 meters, chord of 2 meters, height of 1.7 meters. Canard section profile was a flat plate for both vertical and horizontal surfaces. Take off weight was about 300 kg.

Santos-Dumont started testing his airplane by attaching it to his dirigible No.14 (Fig. 3). He intended to conduct experiments with the airplane stability and control. Those tests produced some good results but were limited in speed by the high drag generated by the dirigible.

He continued with the stability and control tests now by hanging the airplane on a trolley running on an inclined suspended cable (Fig. 4).

It was August 1906 when Santos-Dumont decided to start testing the aircraft at Bagatelle field. After several runs he recognized that the engine was not powerful enough and replaced it with a 50 HP, V-8 Antoinette. Other modifications made during the initial phase of development included elevation of the fuel reservoir, removal of the rear wheel, coating of the wing, reduction of propeller axle length and reduction of wing incidence angle. He deduced that the excessive incidence was slowing down the 14-Bis. He also considered that the side surfaces of the Hargrave's cells would give enough directional stability to the airplane. With those modifications the 14-Bis was able to leave the ground for the first time, during tests, on September 7th 1906.

Santos-Dumont was now decided to try to win the Archdeacon and Aéro-Club de France prizes. On September 13th 1906 he was ready for the first trial before the Aéro-Club members and the habitual crowd. After a failed first attempt, the 14-Bis took off under the enthusiastic applause of the audience, flew 13 meters and made a hard landing, braking the propeller. Ernest Archdeacon and the other Club members run to Santos-Dumont to congratulate him. He did not win the prize but everyone was convinced that the airplane had flown. Santos-Dumont fixed the aircraft and, on October 23rd 1906, he was ready to try again. At four o'clock in the afternoon, after some testing, the aviator climbed on the airplane and started the take off run. The 14-Bis slowly gained speed, rotated nose up and the wheels left the ground smoothly. The airplane flew at a height of about 3 meters then made a slight left turn and landed, 60 meters away from the take off point (Fig. 5). Ernest Archdeacon ran to meet with Santos-Dumont accompanied by a cheering crowd. The repercussion was the greatest possible for the time. The major newspapers in Europe and the Americas announced the conquest of air. The most prominent aeronautical authorities recognized that the heavier-than-air manned flight had been proved.

Santos-Dumont also wanted to win the Aéro-Club de France prize and set the date of November 12th 1906 for the official attempt. During preparations for the flight, he installed two control surfaces inside the outboard Hargrave's cells. Those ailerons were commanded by cables hooked to the pilot's coat shoulders. They were intended to give additional directional control. On the day set for the attempt Voisin showed up to compete for the prize with a biplane he and Blériot had built. Santos-Dumont conceded the lead to his colleague and, after several unsuccessful attempts, Voisin's airplane was damaged and left the competition. During the rest of the day the 14-Bis made four flights. The distance was registered

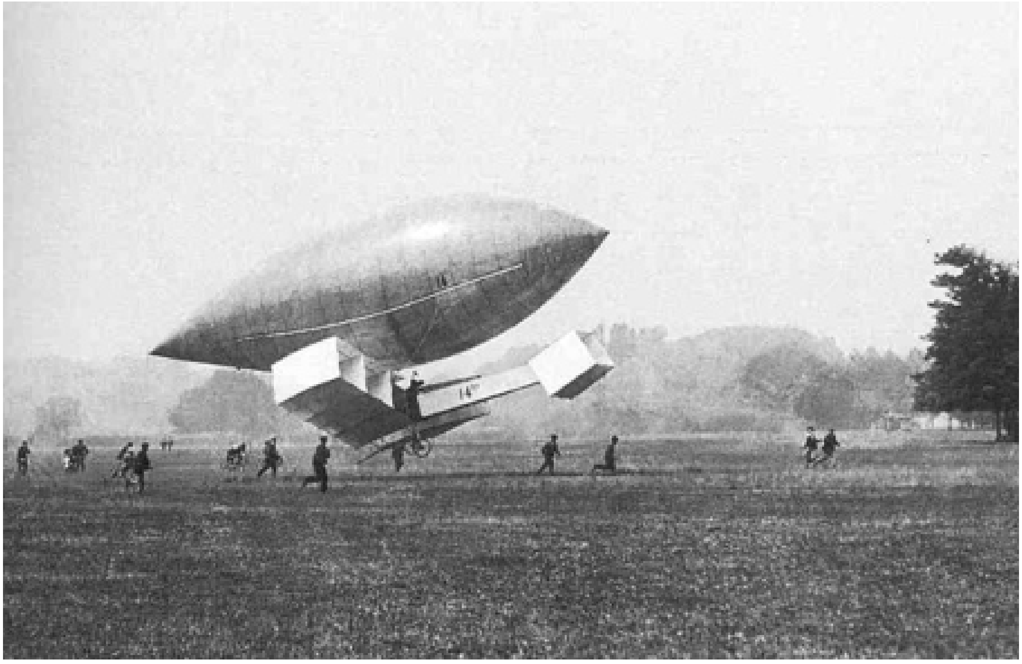

Figure 3: The 14-Bis attached to dirigible No.14 (Musa *et al.*, 2001).

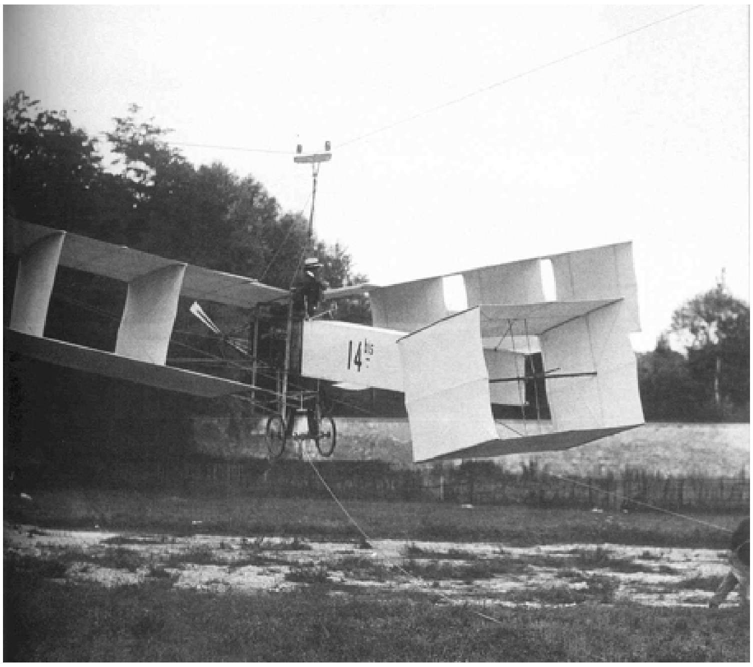

Figure 4: The 14-Bis suspended by cables for stability tests (Musa *et al.*, 2001).

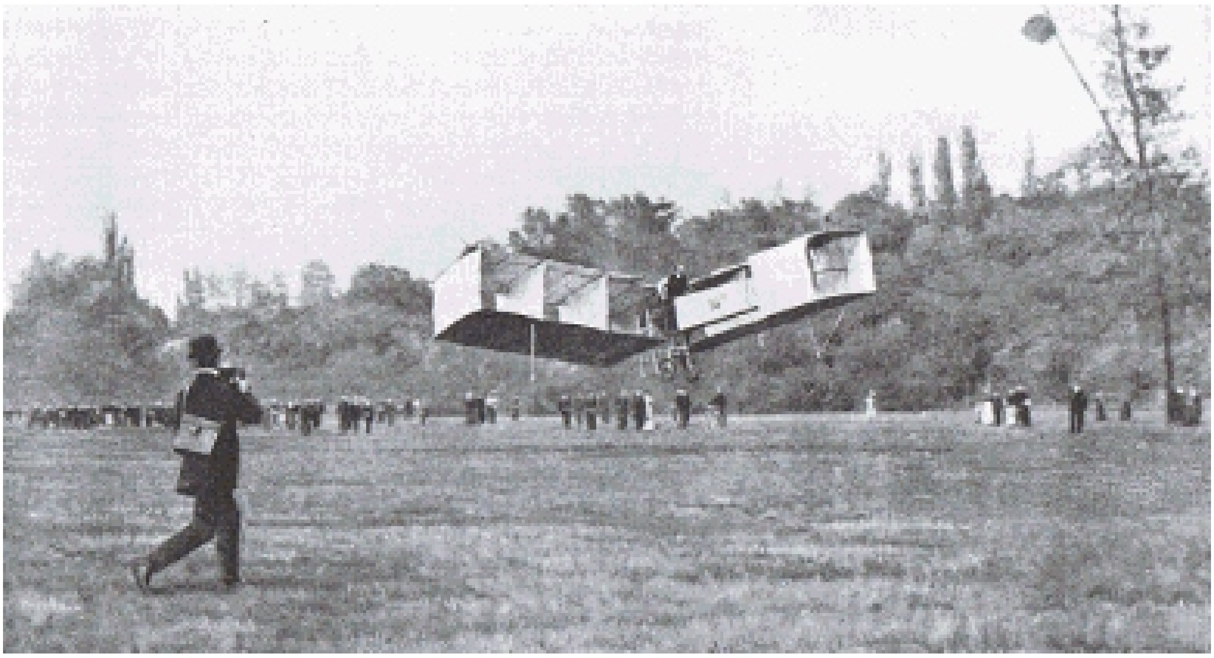

Figure 5: Photograph of Santos Dumont's 14-Bis flight on October 23rd 1906 (Musa *et al.*, 2001).

by plates dropped from a car which followed the airplane running by its side. On the fourth flight, at 4:45 pm, the 14-Bis took off very quickly against the wind. To avoid the crowd, who had invaded the field, Santos-Dumont commanded the airplane to rise to about 6 meters almost reaching stall, made a right turn and, stopping the engine, made a landing. The right wing touched the ground during landing but caused no damage. The chronometers registered 22 seconds of flight and the distance from take off to the landing point was 220 meters. He had won the Aéro-Club de France Prize and set world's first aviation record.

Santos-Dumont tried only once again to fly with the 14-Bis. During that trial the airplane was severely damaged and never repaired. By then he wanted to design new and more efficient aircraft. Recognizing the problems he had to control de 14-Bis, Santos-Dumont designed airplane No.15, still a biplane based on Hargrave's cells but now with the control surfaces in the rear. No.15 never took off and its development was suspended after an accident during a take off run. He then started working on No.16 a hybrid dirigible with a large amount of lift generated by aerodynamic surfaces. Flying attempts failed as it was uncontrollable. Airplane No.17 was a modification of No.15 with conventional biplane wings, a 100 HP engine and three blade propeller. At the same time he built a racing boat , No.18, with the same engine and propeller of No.17, trying to exceed the speed 100 kilometers per hour. Neither No.17 nor No.18 produced good results.

Still in 1907 Santos-Dumont had the idea of building a very light airplane. In 15 days he designed and built No.19, the Demoiselle, an ultralight aircraft with a 8 meter wing span and a 20 HP engine of his own design. By then several European aviators had been able to successfully fly on their airplanes although they still had severe control problems. The Demoiselle was very successful in flying, became very popular and its development continued as No.20, No.21 and No.22 (his last airplane). The Clément-Bayard company sold 50 of those airplanes, each one costing 7,500 Franc. Santos-Dumont never intended to patent his Demoiselle and did not earn any money for his invention. In 1909 Santos-Dumont received the first pilot license from the Aéro-Club de France along with Henri Farman, Louis Blériot, Wilbur Wright, Orville Wright, Léon Delagrange, Robert Esnault-Pelterie and Captain Ferber. He made his last flight as a pilot in January 1910.

3. Geometric Characteristics

An analysis of the 14-Bis flying characteristics requires knowledge of its geometric characteristics. The original aircraft plans, however, are presumed lost, so data on the airplane was collected from several different sources. The original airplane was also destroyed shortly after its last flight. Only the pilot's basket remains stored in a museum (Fig. 6). Basket measured height is 940 mm. Conflicting data was resolved through comparison with actual photographs of the airplane. Photographs can be found in the References listed in this paper but also in the Internet and in museums. The same is true for reproductions of the 14-Bis plans. Figure 7 shows 14-Bis plans made by Sandoval Menezes Lima in 1956. Those plans are stored in the Aerospace Museum of Rio de Janeiro.

Sandoval notes that the underlined dimensions in Fig. 7 have different values in the various sources he used as basis

Figure 6: The original 14-Bis basket (Museu da Aeronáutica).

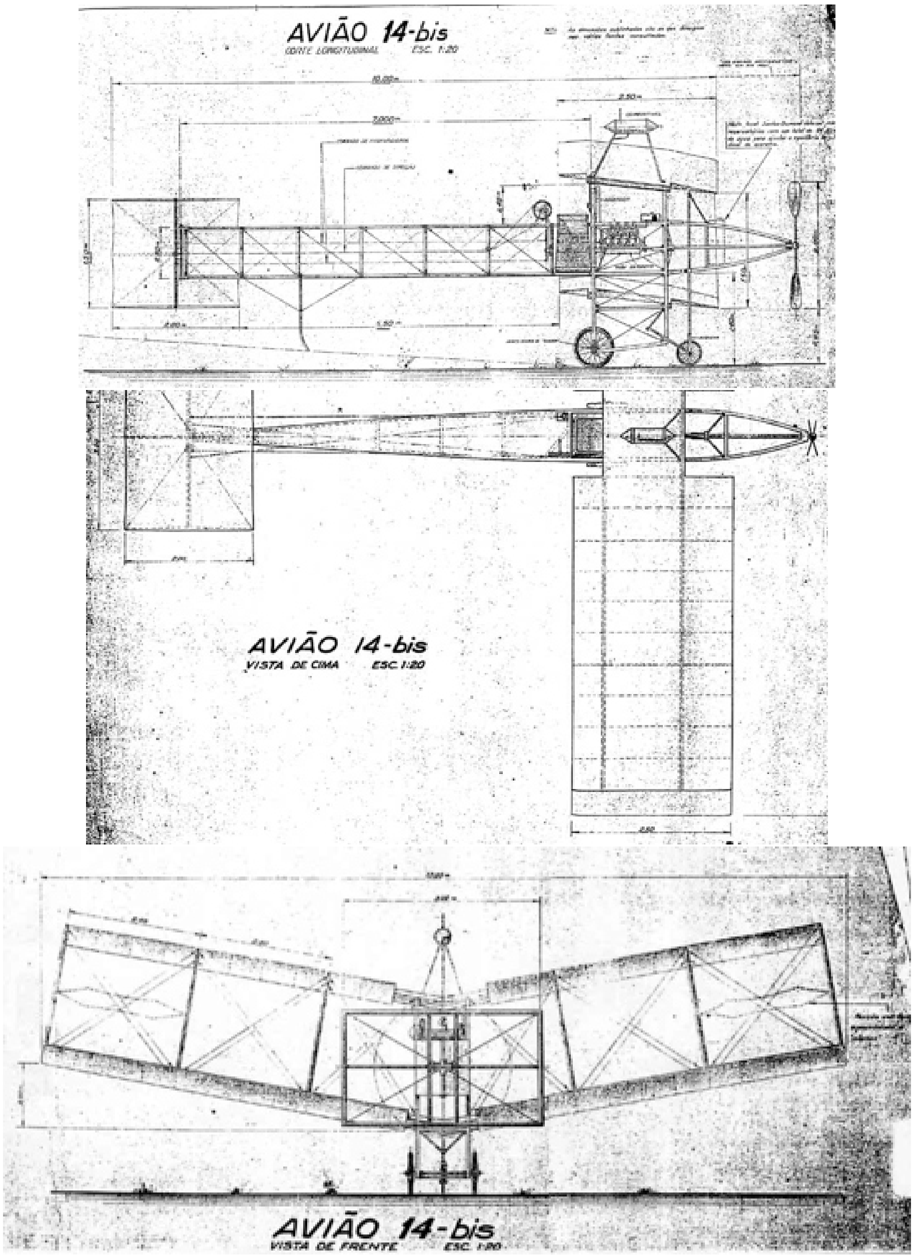

Figure 7: 14-Bis plans obtained from the Aerospace Museum of Rio de Janeiro.

for the drawings. Another plan reasonably accurate is shown in Fig. 8 (Lissarrague, 1983). Comparison of the two plans (Fig. 7 and Fig. 8) shows that the canard dimensions are quite different.

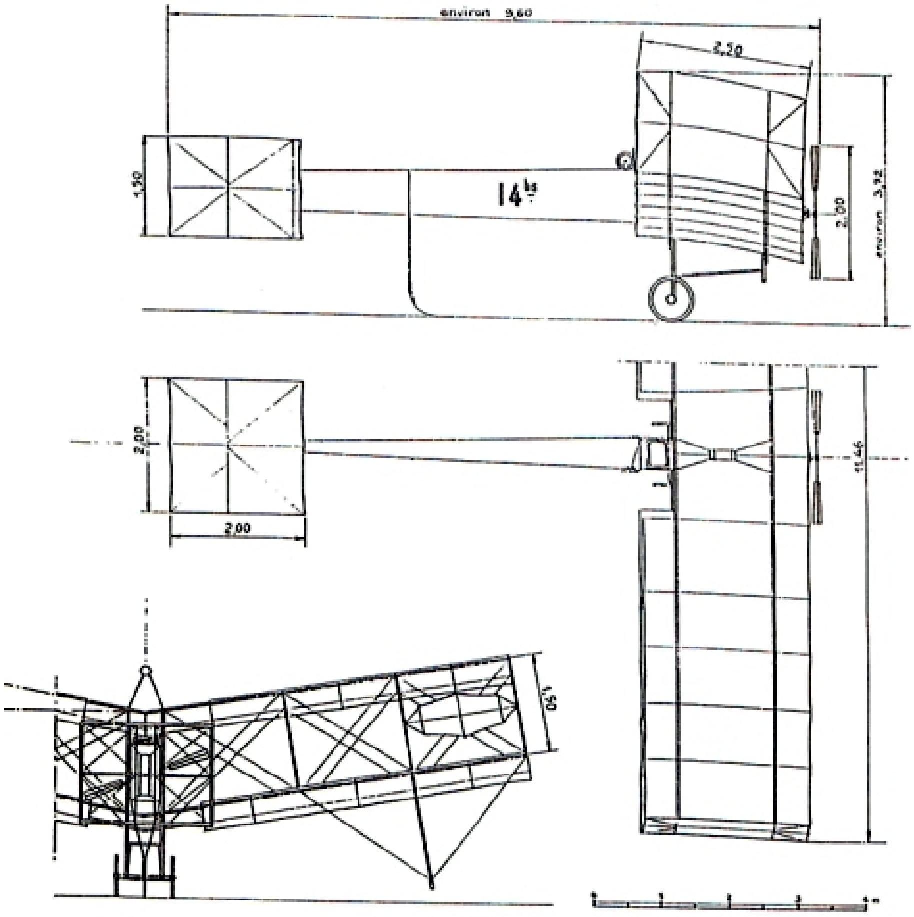

Figure 8: 14-Bis plans reproduced from Pégase magazine (Lissarrague, 1983).

A few replicas of the 14-Bis were built but the ones available for analysis until now are not accurate and could not be used as basis for the present study. Recently a very accurate flying replica was built.

An effort was made to collect and evaluate as much information about the 14-Bis as possible in an attempt to find reasonable values for key airplane dimensions. Even the most accurate available plans such as those of Figs. 7 and 8 contain imprecisions. Photographs of the 14-Bis were used as a basis for verification of the results and a three-dimensional drawing of the airplane was made (Figs. 9 and 10). Some dimensions were extracted directly from the photographs. Scale was resolved using the pilot's basket dimensions (height of 940 mm).

4. Flying Characteristics

After establishing the geometric data, the stability and control derivatives were estimated using first order theoretical methods and a panel method. The center of gravity is estimated to be close to the wing leading edge. The photographs also aided in checking the C.G. position. In Fig. 4, for instance, it can be assumed that the airplane was hung close to its center of gravity. There is indication that Santos-Dumont provided the 14-Bis with means to allow some adjustment of the C.G. position. The stability analysis was conducted with the C.G. located at three different positions close to that indicated by the suspension cable in Fig. 4.

A vortex-lattice panel method code (JkayVLM) was used to estimate the stability derivatives. The three C.G. locations were at 7.0, 7.1 and 7.5 meters from the aircraft nose. Only the most forward position (7.0 m) produced a longitudinally stable airplane. Table 1 shows the longitudinal stability derivatives for that C.G. position.

For that C.G. location the airplane is marginally stable in pitch ($C_{m\alpha}$ close to zero) but unstable in yaw (negative $C_{n\beta}$).

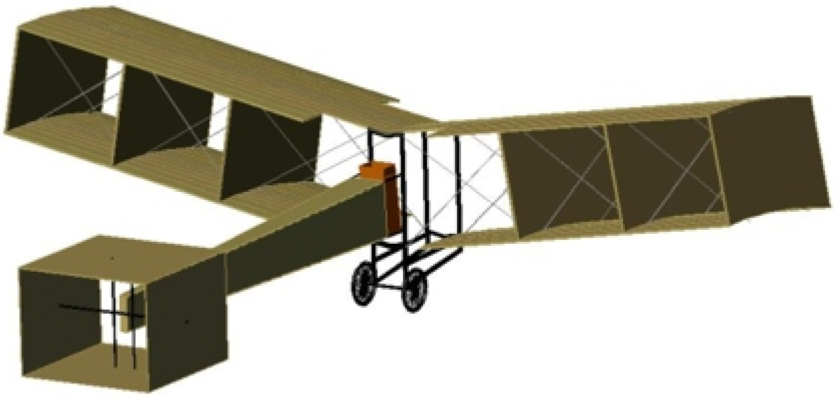

Figure 9: Three-dimensional drawing of the 14-Bis.

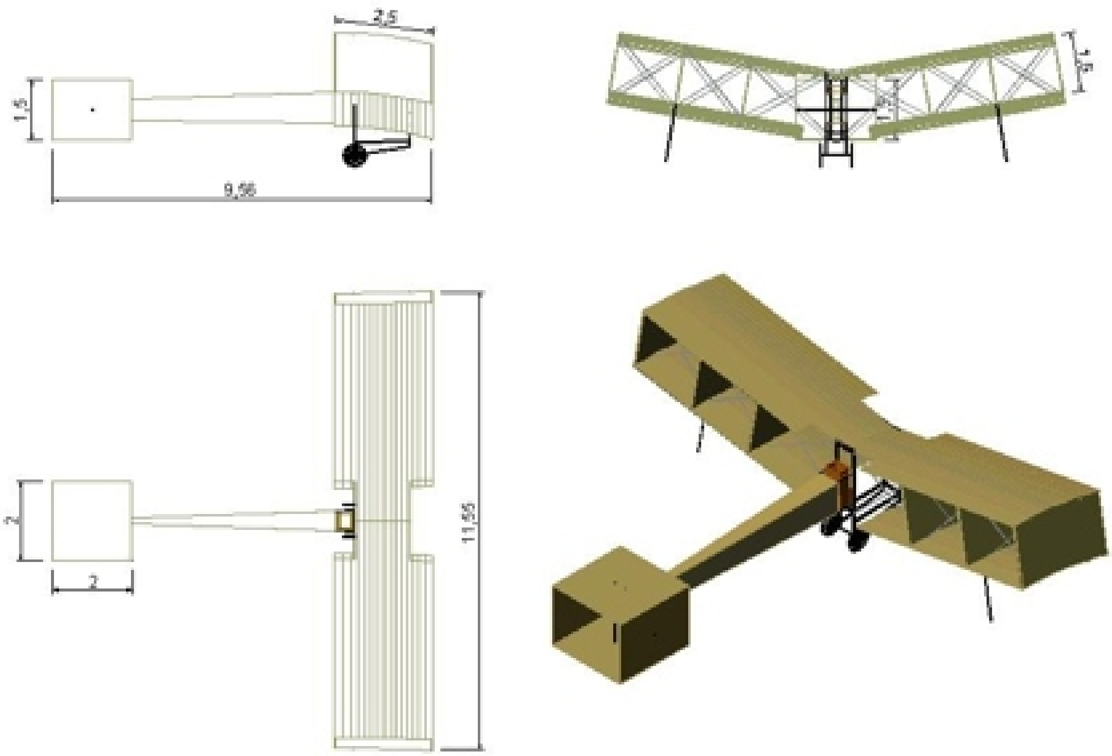

Figure 10: Three view drawing of the 14-Bis.

Table 1: 14-Bis stability derivatives.

Variation of lift coefficient with angle of attack	$C_{L\alpha}$	3.6 1/rad
Variation of pitching moment coefficient with angle of attack	$C_{m\alpha}$	-0.03 1/rad
Variation of lift coefficient with pitch rate	C_{Lq}	4.4 s/rad
Variation of pitching moment coefficient with pitch rate	C_{mq}	-5.4 s/rad
Variation of side force coefficient with sideslip angle	$C_{n\beta}$	-0.12 1/rad
Variation of yaw moment coefficient with yaw rate	C_{nr}	-1.5 s/rad
Variation of rolling moment coefficient with roll rate	C_{lp}	-0.41 s/rad

Santos-Dumont recognized the stability problems, mainly for directional control, saying that "it was like trying to shoot an arrow with its feathers in the front".

5. Conclusion

The geometric characteristics of the 14-Bis were obtained using information from different sources and partially verified through comparison with photographs. Although great effort was made to obtain accurate results they can not be considered as final. This subject still deserves much discussion and perfectly accurate results may never be obtained.

Theoretical estimates for stability and control characteristics indicate that the 14-Bis was marginally stable longitudinally and directionally unstable. The very low speed operation of the airplane would warrant control of those instabilities by the pilot. In fact, recent flight demonstrations of the accurate replica built by Alan Calassa showed a perfectly controlable 14-Bis in straight flight. Controllability of the airplane under cross wind conditions was not accessed in the present study. Again, Alan's demonstrations showed that the 14-Bis could become uncontrollable under cross wind conditions.

This article also tries to summarize the trajectory of Alberto Santos-Dumont as the inventor, the engineer and the pilot who always had the conquest of air as driving force for his work. His contribution to the advancement of aeronautics can not be contested. He not only was responsible for several technical advances but also helped disseminate aeronautics with public demonstrations. Finally, he was a pioneer, setting records and risking his life when so many still believed his objectives were impossible to be accomplished.

6. Acknowledgments

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CFD-BASED ANALYSIS OF THE 14-BIS AIRCRAFT AERODYNAMICS AND STABILITY

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Abstract. *The year 2006 marks the centennial of the historical, heavier-than-air flight by Alberto Santos Dumont with his 14-Bis aircraft. On October 1906, at the Bagatelle Field, in Paris, France, Santos Dumont flew the 14-Bis aircraft and won the Deutsch-Archdeacon Prize. The aircraft had a complex canard-biplane configuration, based on Hargrave's box kites. In this context, the present work describes the results of a CFD-based analysis of the 14-Bis aircraft aerodynamics and flight stability. The 14-Bis aircraft CAD geometry was generated from historical resource observations. CFD computations are performed using well-established commercial and proprietary codes for calculation of the historical flight conditions. The computations consider a Reynolds-averaged Navier-Stokes formulation, in which turbulence closure is achieved using Menter's SST model. The calculations consider unstructured grids and the codes feature a multigrid method for convergence acceleration. The flight conditions investigated are primarily concerned with historical observations regarding flight speeds and the need for a more powerful engine, as well as flight stability characteristics of the 14-Bis airplane, which are unknown up to the present day. The results lead to qualitative agreement with historical reports, although quite interesting conclusions can be drawn with regard to actual aerodynamic flight speeds and aircraft stability parameters.*

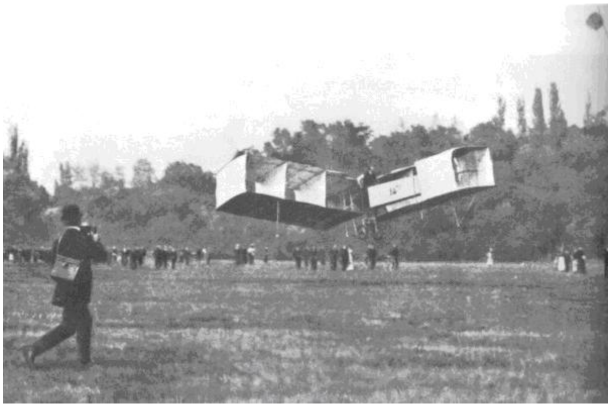
keywords: *Aerodynamics, CFD, Centennial of Flight, Santos Dumont, 14-Bis*

1. Introduction

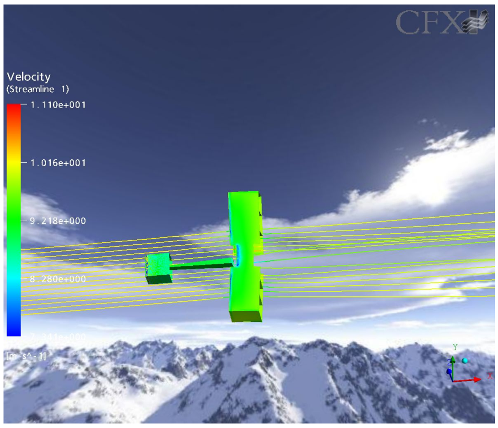
Alberto Santos-Dumont, native from Brazil, was a genius obsessed with the idea of flight. First working on balloons and dirigibles, and latter designing engine-powered vehicles, he became one of the best-known men in Paris. On October 23, 1906, in the Bagatelle Field, Paris, France, Santos Dumont flew the 14-Bis aircraft and won the Deutsch-Archdeacon Prize. The 14-Bis aircraft was constructed from pine and bamboo poles covered with Japanese silk. The aircraft had a complex canard-biplane configuration, which was a construction based on Hargrave's box kites. The Hargrave cell in the nose pivoted up and down to act as an elevator and from side to side in the role of a rudder. The wings were rigged with 10 deg. of dihedral and the first flights were made without ailerons. The preliminary flight test happened with the 14-Bis aircraft attached to the No 14 dirigible, which explains its designation.

The 14-Bis flew without the dirigible on September 13, 1906, making a hop between 6 and 13 meters. According to an article published in Pegasse magazine, after having achieved partial success in his flight attempt, Santos Dumont identified possible problems with the 14-Bis configuration, and performed the following improvements:

- Elevation of the gas tank;
- Application of varnish on the silk to diminish the porosity;



(a) 14-Bis in flight 23 October 1906 - Source: Museu Aeroespacial.



(b) CFD simulated model over the mountains.

Figure 1: The historical first flight and a CFD simulated model.

- Taking the back wheel off;
- Decrease of the wing incidence angle;
- Upgrade of the original power-plant, replacing the Antoinette 24 hp engine by a 50 hp version.

On October 23, Santos Dumont managed to fly for 60 meters as illustrated in the left of Fig. 1. Then, on November 12, he flew 220 meters in 21 1/2 seconds with members of the Aero-Club de France in attendance. Santos Dumont won a prize of 1500 francs for making the first flight over 100 meters in Europe. Since he was observed by officials from what would become the Federation Aeronautique Internationale, Santos Dumont was credited with making the first heavier-than-air powered flight. The main 14-Bis geometric characteristics are presented in Tab. 1.

Table 1: Historical 14-Bis geometric characteristics.

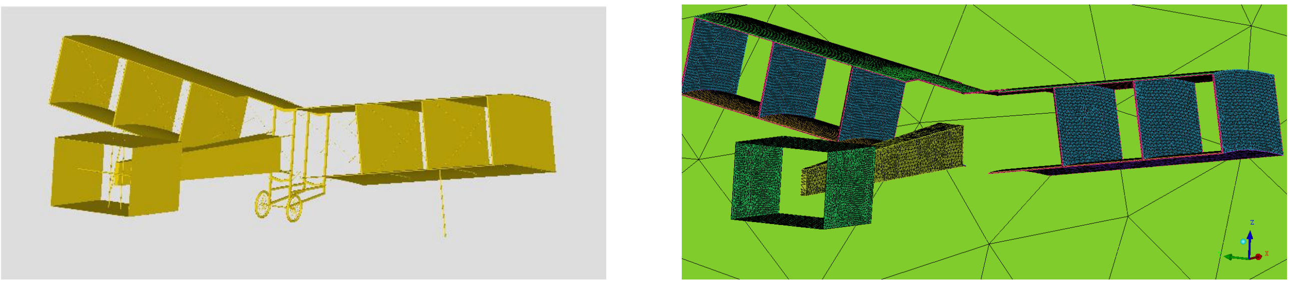
Total Canard Area	8 m^2	Length	10 m
Canard Chord	2 m	Engine Power	24 hp(first) - 50 hp
Canard Span	2 m	Weight with Pilot	$\approx$ 315 kg
Wing Chord	2.5 m	Historical Cruise Flight Speed	9 to 12 m/s
Wing Span	11.50 m	Wing Chord Reynolds Number	10^6
Wing Dihedral	10 deg.	Canard Chord Reynolds Number	10^7
Total Wing Area	50 m^2	Canard-Wing Distance	5 m
Center of Gravity (X_{cg}) Estimate$^{(1)}$	7.5 m		

$^{(1)}$: Reference point is aircraft nose.

During a long time, there were only two approaches for aerodynamic studies, wind tunnel testing and analytical solution of simplifications to the Navier-Stokes equations. The last method is very limited, since only some simple cases can be predicted with acceptable accuracy. The wind tunnel also has some disadvantages, such as high energy consumption, and a considerably large time spent constructing the model, performing the tests, and processing the data. Moreover, only some flow conditions can be reproduced. It must be pointed that those factors together are related to more costs.

Computational fluids dynamics (CFD) techniques emerge as an alternative able to reduce project costs, since time and money spent with wind tunnel testing are substantially reduced. In addition to this, CFD has the advantage of numerically solving the fluid equations in the entire flowfield, thus allowing for local analysis of the flow properties in a way much more detailed than any wind tunnel visualization techniques could show. But, in spite of CFD advantages, wind tunnel tests still are an indispensable stage of every aircraft project, since this is as similar to physical reality as possible.

The main objective of this article is to apply CFD techniques for aerodynamic analyses of the 14-Bis aircraft. The central idea is to compute lift and drag curves for this aircraft, at the presumed flight conditions, and then assess and clarify some controversial points regarding stability, flight speed, ground effect and power plant performance. The study will also explore angle of attack and velocity variations around the historical flight conditions.



(a) Original CAD model. (b) Mesh view of idealized configuration.

Figure 2: Comparative view of the original CAD model and simulated configuration.

2. Theoretical Formulation

2.1. Reynolds-Averaged Navier-Stokes Equations

These equations constitute the more general flow formulation for which the fluid continuum hypothesis can be assumed. The Navier-Stokes equations, for a perfect gas, without the generation of heat and with negligible field forces can be written as

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u_j)}{\partial x_j} = 0 \quad , \tag{1}$$

$$\frac{\partial (\rho u_i)}{\partial t} + \frac{\partial (\rho u_i \, u_j)}{\partial x_j} + \frac{\partial p}{\partial x_i} - \frac{\partial \tau_{ij}}{\partial x_j} = 0 \quad , \tag{2}$$

$$\frac{\partial e}{\partial t} + \frac{\partial [(e+p)\, u_j - \tau_{ij}\, u_i + q_j]}{\partial x_j} = 0 \quad , \tag{3}$$

where ρ, p and $\vec{u}$ are the fluid density, pressure and velocity, respectively, $\vec{\vec{\tau}}$ is the viscous stress tensor, $\vec{q}$ is the heat flux vector and t is the time. The term e is the total energy per unit of volume, given by

$$e = \rho \left[e_i + \frac{1}{2}(u^2 + v^2 + w^2) \right] \quad , \tag{4}$$

where u, v and w are the velocity vector Cartesian components and e_i is the internal energy.

In the formulation, two assumptions were adopted: the absence of heat transfer, i.e., the heat flux vector terms equal zero, and the flow was treated as incompressible due to the low flow Mach number values (lower than 0.05). To save computational memory and processing capabilities, the turbulent flow analyses are performed using the Reynolds-averaged Navier-Stokes equations. These equations contain the mean variables and a certain number of terms representing the turbulence effects that must be modeled.

3. Numerical Approach

3.1. Flow Solver

The computations on unstructured grids have been carried out by CFX (2005) which is a software capable of performing the analysis and solution of complex internal and external three dimensional flows. The solutions of the turbulent flow regions were based on the Reynolds-averaged Navier Stokes equations (RANS), supported by Menter's SST turbulence model (Menter, 1994).

The CFX solver simulated a steady, viscous and incompressible flow around the 14-Bis model. This code uses a cell-vertex, finite element-based control volume method. An iterative, second order, time marching scheme is used to numerically solve the RANS equations. To decrease the computational time, some convergence acceleration techniques, such an algebraic multigrid (MG) procedure, and parallel computations are used during the simulations.

3.2. Grid Generation

The 14-Bis CAD geometry was generated from planform and historical source observations and it was provided by Prof. Greco's research group at University of São Paulo, São Carlos campus. Around the geometry, the flow domain was discretised using unstructured grids. Since memory and processing capabilities were limited, the geometry was simplified keeping only the main components, i.e., wings, canard and fuselage. Figure 2 makes a parallel between the original geometry and the simulated one.

The grid generator software used (ICEM-CFD, 2005) allows the automatic generation of the tetrahedrical grid. However the superficial mesh over the airplane had a poor arrangement. The strategy adopted was to first create a structured 2-D grid over the geometric surface, and, after that, the Delauney method (Field, 1987) was applied, generating the desired unstructured volumetric grid. The element transitions were performed gradually to assure faster convergence and good solutions. Furthermore, regions of leading edges, trailing edges and the ones probably containing wakes received grid refinement to avoid spurious solutions.

3.3. Boundary Conditions

The correct application of boundary conditions is vital to properly close the numerical problem, assuring correct modeling. For the 14-Bis aircraft simulation, basically four different boundary conditions are used: INLET, OUTLET,OPENING, SLIP WALL and NO-SLIP WALL. The nomenclature used here is the same adopted by the CFX solver.

INLET condition is applied on the computational domain entrance surface where the freestream velocity magnitude and its direction are specified. NO-SLIP WALL condition assures that neither tangential nor normal velocity are present on the aircraft surface. The OUTLET condition is used to model the fluid flow exit in the domain. The OPENING condition models a boundary condition which permit entrance and exit of fluid freely. SLIP WALL condition is used on the surface just below the airplane in the simulations concerned about the the ground effect verification. For all the other test cases, the boundary treatment of that surface considered the OPENING condition. All boundary conditions prescribed are listed in Table 2.

Table 2: Detailed description of prescribed boundary condition on domain surfaces.

Surface	Type	Description
Aircraft	NO-SLIP WALL	The normal and tangential velocity components are kept zero.
Ground	SLIP WALL	On the surface below the airplane, the normal velocity component is zero.
Entrance	INLET	Entrance conditions are specified to the freestream conditions.
Exit	OUTLET	The atmospheric pressure is specified as exit pressure.
Lateral sides	OPENING	The atmospheric pressure is specified.

3.4. Post-Processor for Aerodynamics Forces

The post-processor, by means of simple and useful tools, allows evaluation of aerodynamics forces and the observation of the flow field variables, for example, pressure contours, streamlines or boundary layer velocity profiles. The resultant force in the airplane, when projected into the wind axis results in drag, lift and yaw forces. The evaluation of these aerodynamic forces is performed by integrating the surface pressure forces and shear stresses as shown in Eq. 5. More detailed description of these method can be found in Cummings *et al.* (1996).

$$\vec{F}_{near} = \int_{S_{near}} \left[(p - p_\infty)\,\vec{\vec{I}} - \vec{\vec{\tau}} \right] .\vec{n} dS \quad . \tag{5}$$

The aerodynamic drag is a force exerted by the flowfield on the body surface in a direction contrary to its movement in the air. The drag is the summation of the tangential, or skin friction forces, and surface pressures or normal forces, projected into the freestream direction.

By evaluating forces and moments over the airplane for several flight conditions, *i.e.*, varying the angle-of-attack (α), or the canard angle (δp), the authors were able to extract important aerodynamics coefficients, and draw conclusions about the 14-Bis flight condition and possible stability range.

4. Test Cases

The chosen test cases try to explore the main aerodynamic characteristics of the 14-Bis airplane. This is done through a parametric study shown in Table 3. The freestream velocity variation permits attest the invariability of the aerodynamic coefficients with the flight speed.

The simulations, including angle of attack (AoA) and canard deflection excursions, allow for estimates in lift, drag and pitching moment derivatives. Assuming steady level flight and using the estimated aerodynamic derivatives and coefficients, a possible flight condition could be estimated. Moreover, the ground effect influence is checked out varying the distance of the airplane from the ground.

Table 3: Simulated test cases for the parametric study of the main aerodynamic characteristics of the 14-Bis airplane.

Set	Parameter	Description	Variation	General Conditions
1	V_∞	Velocity	7.5 to 14 m/ s	Variation of $V_\infty, \alpha = 0$ deg., δ_p=0.
2	α	Angle of Attack	-5 to +6 deg.	Variation of α, $V_\infty = 11.5 m/s$,δ_p=0.
3	δp	Canard Deflection	0 to +7.5 deg.	Variation of δ_p, α kept zero.
4	β	Sideslip angle	+1 to +7 deg.	Variation of β, $\alpha = 5$ deg.
5	Δ	Ground Distance	0 to 6 m	Variation of Δ, $\alpha = 5$ deg.

It is worth noting that all the test cases with fixed speed had the value 11.5 m/s adopted as default. That is because 11.5 m/s is an intermediate speed between the historical report of 10.21 m/s and the previously estimated value using numerical simulations (Bitencourt *et al.*, 2005). It is also important to mention that all the moment coefficients were calculated in relation to an estimated center of gravity (CG) position (Greco and Ribeiro, 2003). Its horizontal position was estimated at a point lying around 7.5 m from the airplane canard frontal extremity. The CG vertical position was estimated to be on the fuselage centerline.

5. Results and Discussion

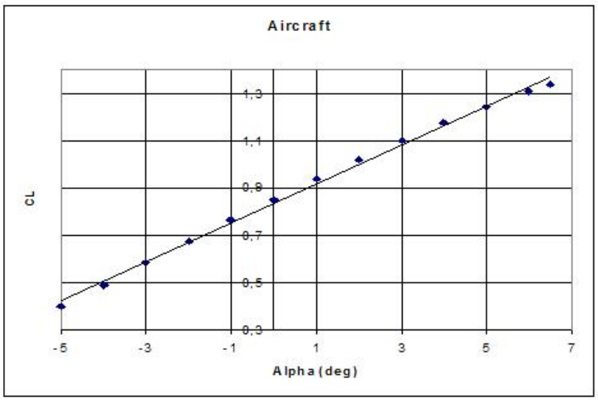
Results obtained for the first set of test cases (see Table 3) verified an expected absence of flight speed influence over the aerodynamic coefficients. The results show a maximal relative difference of 0.29 % for C_L, 2.48 % for C_D and 1.09 % for Cm, in the speed range analyzed. Those small variations indicated that the aerodynamic coefficients can be considered independent of the flight speed. This hypothesis supports the use of a linear aerodynamic model, when performing flight dynamics and performance estimates in a range of flight speeds around the historical value.

The second and third sets of test cases (see Table 3) led to obtaining the aerodynamic coefficients and derivatives needed to perform an analysis of the aircraft longitudinal behavior. Figure 3 shows the $C_L \times \alpha$, $C_m \times \alpha$, $C_D \times C_L$ and $L/D \times \alpha$ curves that were obtained for the whole aircraft. The authors would like to note that all coefficients presented here were made dimensionless using the wing planform area and the wing mean chord. Figure 4 shows the $C_m \times \delta_p$ and $C_L \times C_{\delta_p}$ curves which are necessary for extraction of control derivatives.

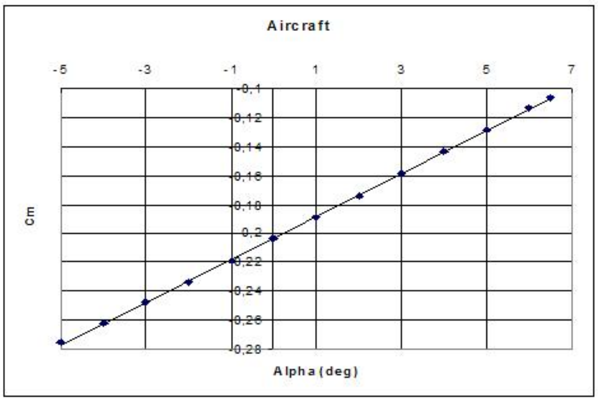
The test cases clearly explore the flight conditions in which the airplane has a linear aerodynamic behavior,*i.e.*, the aerodynamic coefficients change linearly with the AoA and canard deflection variations. The resultant aerodynamic coefficients and derivatives for the aircraft and canard are listed in Table 4. For higher or lower angles, unsteady solutions were found, but not completely simulated due to computational restrictions. An aspect that should be pointed out is the wing incidence angle of approximately 5 deg. used in the 14-Bis aircraft.

The plots in Figs. 3 and 4 carry much information about the aerodynamic performance. For example, $C_{m\delta p}$ corresponds to 153 % of C_{m_α} and $C_{L\delta_p}$ is just 9.3 % of $C_{L\alpha}$, meaning that the canard seems to be effective to perform its principal function, the aircraft pitch control. However, a remarkable point is that the aircraft resultant moment increases with the AoA, meaning that the airplane is unstable what would, at least, demand great pilot effort to control the flight.

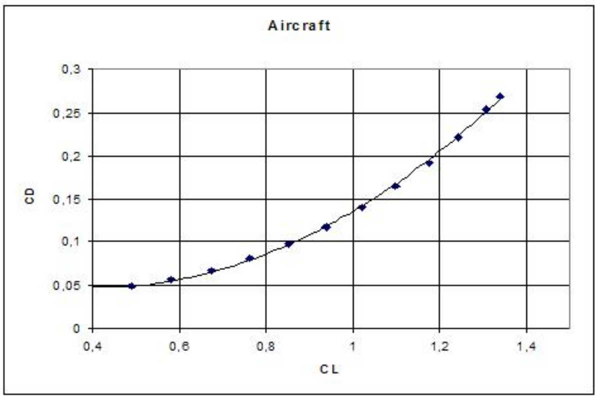
A detailed discussion about stability is addressed ahead. The downwash effect of the canard over the wing was also checked out, and, as expected, negligible variations in the wing aerodynamic coefficients were observed with different canard deflections. The inverse, *i.e.*, the upwash caused by the wing over the canard can be verified if one notes that the canard generates about 9.7 N of lift, without deflection, even though the canard



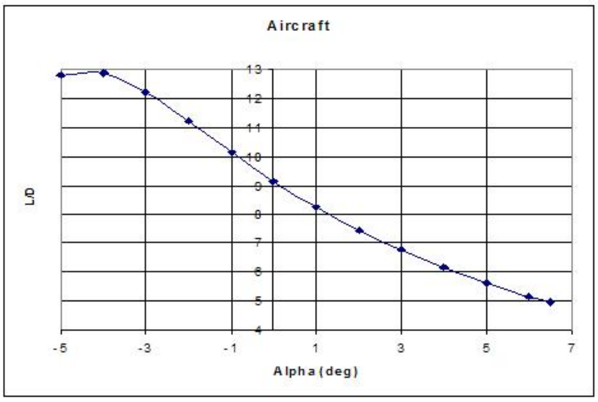
(a) $C_L \times \alpha$ curve for the airplane.



(b) $C_m \times \alpha$ curve for the airplane.



(c) Drag polar for the entire airplane.



(d) $L/D \times \alpha$ curve for the airplane.

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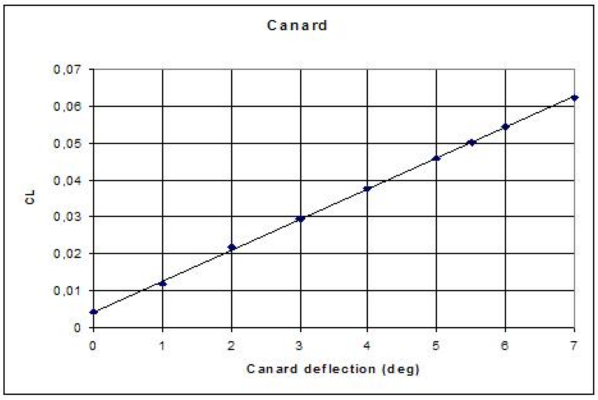
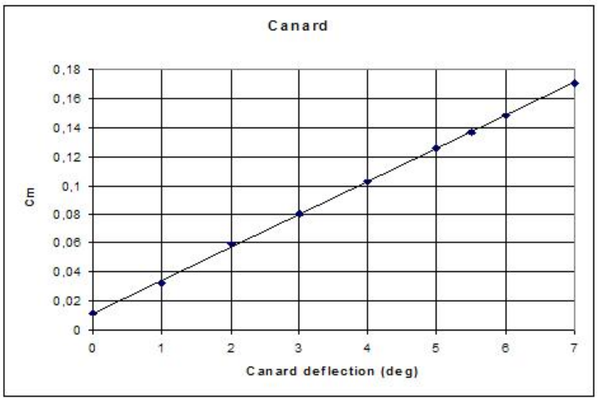


(a) $C_L \times \delta_p$ curve for the canard.



(b) $C_m \times \delta_p$ curve for the canard.

Figure 4: Aerodynamic coefficients for the canard keeping zero angle of attack for the airplane.

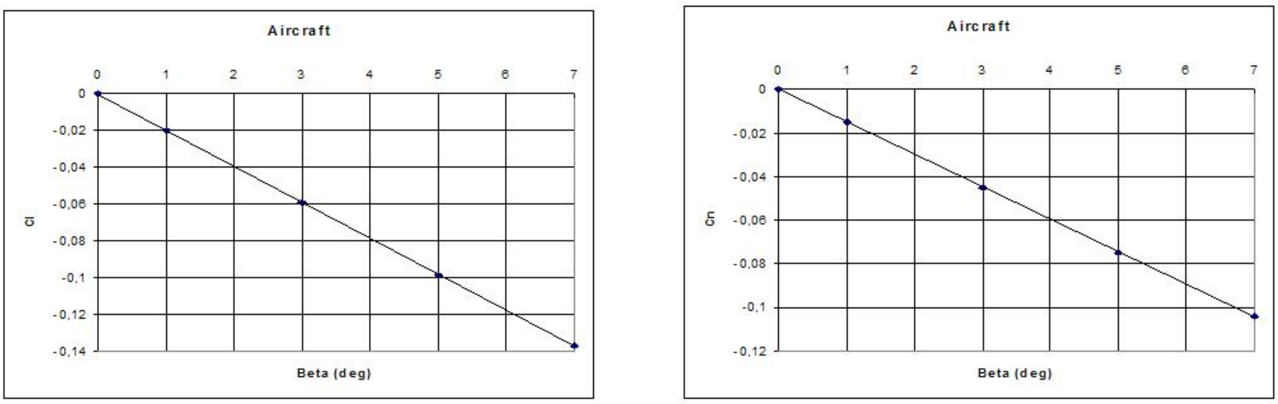
Table 4: Aerodynamic coefficients and derivatives of the airplane and control surfaces.

AIRPLANE		CANARD	
$C_{L\alpha}$	4.85	$C_{L\delta_p}$	0.45
C_{m_α}	0.85	$C_{m\delta_p}$	1.31
C_{m_o}	-0.21		
C_{Lo}	0.85		
C_{Y_β}	-1.76		
C_{n_β}	-1.20		
C_{l_β}	-1.12		

is modeled by means of flat plates. This effect is not noticeable in terms of total lift, but a significant pitch moment about the aircraft CG is added, since the CG position was estimated to be placed between 7.0 m and 7.5 m from the aircraft nose.

The aerodynamic efficiency, L/D, for different angles of attack can be seen in Fig. 3(c). The loss of efficiency as the angle of attack increases is quite notable. For instance, a variation of 61 % in the L/D value is found given the range of 12 deg. studied. This is most probably related to a large amount of induced drag produced by the aircraft.

In the fourth test case, the influence of lateral flow by varying sideslip angles on the airplane was evaluated. In doing so, some clues to analyze potential risks of a lateral flow, or even gusts could be tested. Just looking at the plots in the Fig. 5, the linear approximation for the stability derivatives seems perfectly reasonable and their values are listed in Table 3. As can be observed, the sideslip angle induces significant and equally important roll and yaw moments. Such a statement can be made because both coefficients have the same order of magnitude. This points out a coupling between roll and yaw moments, which is an underlying characteristic of this airplane. The numerical results have also shown that lateral flow exerts negligible influence on the longitudinal coefficients, namely C_L, C_D and C_m, having a maximum relative variation of 3 % along the sideslip angle range tested.



(a) $C_l \times \beta$ curve for the airplane.

(b) $C_n \times \beta$ curve for the airplane.

Figure 5: Aerodynamic coefficients for the airplane under sideslip.

In order to analyze the flight conditions, a linear aerodynamic model was used. The aerodynamic derivatives and coefficients shown in Table 4 are used to predict the lift, drag and moment coefficients as follow

$$C_L = C_{Lo} + C_{L\alpha}\alpha + C_{L_{\delta_p}}\delta_p \quad (6)$$

$$C_M = C_{mo} + C_{m\alpha}\alpha + C_{m_{\delta_p}}\delta_p \quad (7)$$

$$C_D = 0.892 - 0.206C_L + 0.252C_L^2 \quad (8)$$

Before applying this methodology, its accuracy was verified. The model predictions were directly compared with the CFD data. The relative differences between the model and the CFD results were always less than 10 %, with the exception of the three highest canard deflection angles. Consequently, the linear model was adopted for the study of flight conditions because the accuracy fits under the expectations.

The exact CG position is unknown and, therefore, conclusions concerning the 14-Bis aircraft stability are only as good as the estimates of CG position. The stability criterium states that an airplane is stable if, when perturbed from its equilibrium condition, restorative moments bring the airplane back to the equilibrium condition. Estimations of the mass of each airplane component (Greco and Ribeiro, 2003) found a range between 7.0 m and 7.5 m for the CG position, measured from the airplane nose.

If the pitch moment derivative (C_{m_α}), which comes from the curve $C_m \times \alpha$, is positive, the airplane is considered unstable, otherwise, stable for negative values and neutral for a zero value. The numerical results indicates an unstable condition for CG positions higher than 6.87 m. Therefore, the 14-Bis could be an unstable airplane if the estimated range for CG positions were right.

First, the authors would emphasize that unstable airplanes can fly, however their controllability is more difficult. Second, Santos Dumont could have changed the CG position by adding sufficient weights to turn the airplane stable.

The estimated flight conditions were studied considering the flight as being steady and level, *i.e.*, the speed derivative ($\dot{V}$), the AoA derivative ($\dot{\alpha}$), and the resultant moment at the center of gravity are all zero. Those constraints turn the differential system of equations for the longitudinal dynamics into a simplified nonlinear system with three equations and four unknown variables,

$$F_e\, cos(\alpha_e) - D_e = 0 \quad , \tag{9}$$

$$L_e - mg + F_e\, sin(\alpha_0) = 0 \quad , \tag{10}$$

$$C_{mo} + C_{m\alpha}\alpha + C_{m_{\delta_p}} = 0 \quad , \tag{11}$$

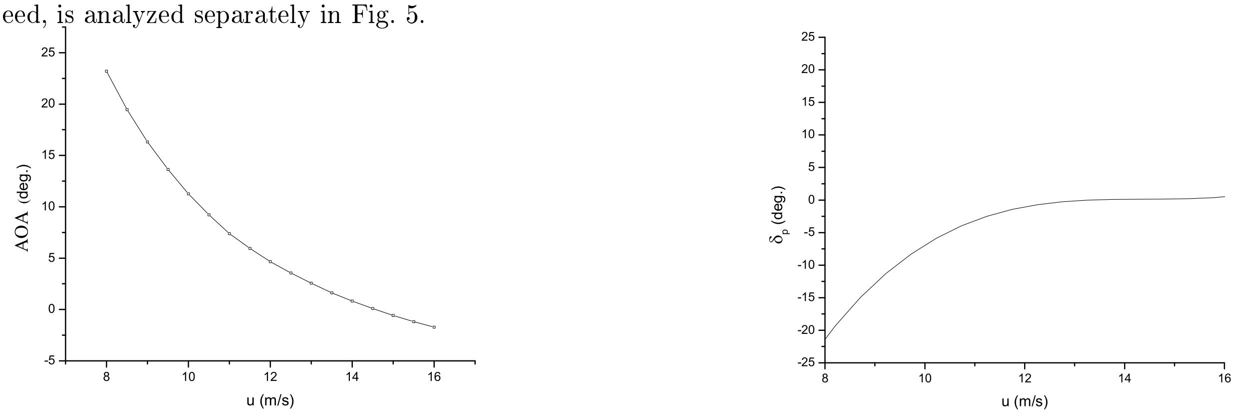
in which,

$$L_e = q_\infty\, S_w\, C_L \quad , \tag{12}$$

$$D_e = q_\infty\, S_w\, C_D \quad . \tag{13}$$

Here, q_∞ is the freestream dynamic pressure, given in its standard definition as $q_\infty = \rho V^2/2$, S_w is the wing planform area, and mg is the airplane weight. C_L is the lift coefficient, and C_D is the drag coefficient, as shown in Eqs. 6 and 8, respectively. The remaining coefficients are all listed in Table 4. Moreover, the four unknown variables are flight speed (V), AoA (α), canard deflection (δ_p) and required thrust (F_e).

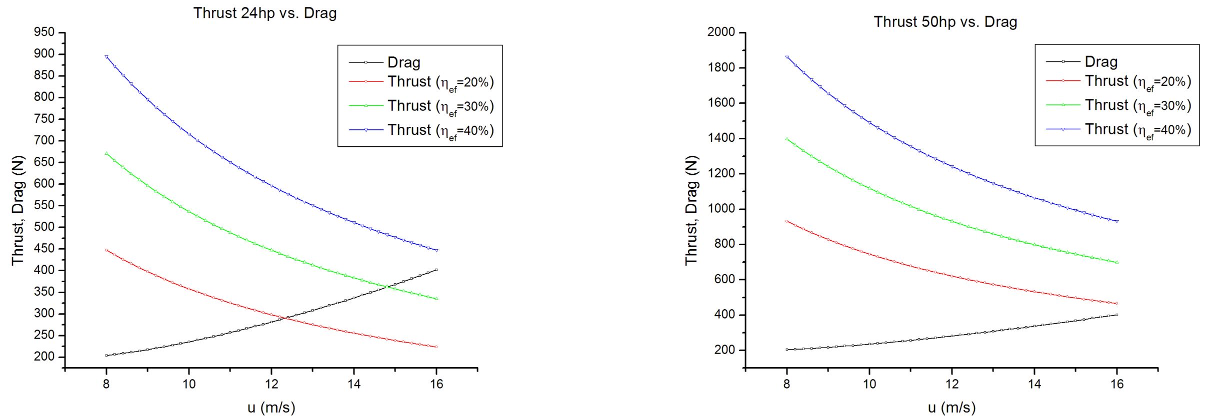
That system of equations does not have only one solution, but it has infinite solutions. The adopted procedure to study the steady flight condition is to find the equilibrium state for each flight speed. Figure 5 shows the necessary AoA and canard deflection for each flight speed. The third condition, the required propulsion for each speed, is analyzed separately in Fig. 5.



(a) AoA necessary to maintain permanent flight for each flight speed.

(b) Canard deflection required to maintain permanent flight for each flight speed.

Figure 6: Study of flight conditions parameterized by the flight speed.



(a) Drag and thrust dependence with velocity for the 24 hp engine.

(b) Drag and thrust dependence with velocity for the 50 hp engine.

Figure 7: Study of thrust requirements for sustained flight.

The adopted procedure to investigate the most probable flight condition consists in discarding high AoA and canard deflection, in which surely the airplane would experience stall, followed by an analysis of the propulsive requirements. In addition, the historical pictures and reports provide auxiliary clues that validate the numerical model.

The numerical results show that a sustained flight within the linear range is perfectly feasible. The suggested flight conditions are AoA between 5 deg. and 10 deg., canard deflection between -5 deg. and 5 deg., as well as, the flight speed between 11 m/s and 14 m/s. Looking at the historical picture in Fig. 1, the observable flight condition evidence AoA in the range 5 deg. to 10 deg. and an almost imperceptible canard deflection. Such condition could be attested in Fig. 6.

The next step verifies the propulsive requirements to overcome the generated drag. It is important to note that the thrust produced by the engine decreases as the flight speed increases. As the true propulsive efficiency (η_p) is unknown, three isolines of different η_p, with values 20 %, 30 % and 40 %, are considered in the present analyses, considering both the 24 hp and the 50 hp engines. Furthermore, one should also note that both engine power and propulsive efficiency values are in agreement with the historical records (Vilares, 1956).

The propulsive analysis with the 24 hp engine in Fig. 5(a) permit to say that the flight is viable, however having very restrictive conditions. For example, for speeds larger than 12.4 m/s, flight is not possible if the actual propulsive efficiency of the aircraft was closer to the lower limit here considered, *i.e.*, 20 %. Some factors should be carefully observed about drag and thrust estimated values. First, due to geometric simplifications, the CFD drag results here reported are probably lower than the actual drag in flight. As a result, the drag curves in Figs. 5(a) and 5(b) should be shifted upwards, further restricting the admissible flight speed range and bringing the probable flight speed closer to the historically reported one. Moreover, during takeoff, ground effect causes additional drag and lift forces.

The fifth test case set in Table 4, detected an increase of 6 % to the lift and only 3 % to the drag relative to the condition without ground effect. The power deficiency of the 24 hp engine became evident on September 13, 1906, during a flight attempt, when the aircraft, in spite of some jumps, was unable to take off. During the following experiments, a new and more powerful engine was selected. Its nominal power was 50 hp at 1500 rpm (Vilares, 1956). The propulsive analysis with the new 50 hp engine clearly evidences that the propulsive restriction was overcame, allowing sustained flight in the complete speed range showed, even with the smaller value of propulsive efficiency.

6. Conclusions

The present work has used CFD techniques to perform an aerodynamic evaluation of the 14-Bis aircraft configuration. The historical flight conditions are simulated using a finite volume method and solving the RANS equations with the Menter SST turbulence model. A geometrically simplified model of the aircraft is used and the results obtained so far seem to corroborate many of the historical reports.

The results presented in the previous section confirmed why the 24 hp engine was unable to allow the 14-Bis aircraft to take off during the first flight attempt on September 1906. Therefore, the engine change, selecting a more powerful one with 50 hp, is clearly justified. Based on the present calculations, it is difficult to believe that 10.21 m/s was the true airspeed of the aircraft, because the AoA vs. speed curve, that was generated during the simulations, indicates that an AoA of approximately 10 deg. is required to maintain sustained flight at this speed. If one adds such an aircraft angle of attack to the 5 deg. wing incidence, it is clear that the airplane would be in a stall condition. An acceptable flight speed, assuming a 5 deg. angle of attack, seems to be around 12 m/s. Such speed could be reached more easily when flying against the wind direction. In any event, it can be stated, based upon the present numerical results, that the flight speeds should have been higher than 12 m/s. The results further indicate that, considering the 50 hp engine, the availability of thrust was not a limitation to the flight.

The analysis of longitudinal static stability considered the linear regime and it has shown that the estimated position of the neutral point is coherent with historical reports. Moreover, the parametric tests demonstrate that small center of gravity position variations, around the historical point, could render the aircraft statically unstable. This study concerning longitudinal static stability has emphasized that the CG position seems to be a critical factor for the 14-Bis flight. However, it must be stated that, as cited in Greco and Ribeiro (2003), Santos Dumont used to modify the CG position by adding weights to alter the CG location, leading the aircraft to a stable condition.

A well defined range of flight conditions is found, namely AoA between 5 and 10 deg., canard deflections between −5 and 5 deg. and flight speeds between 11 and 14 m/s. This indicates that the possible flight conditions are, in fact, wider than the historical values usually cited. Other important aircraft characteristics are identified, such as the roll and yaw coupling when subjected to lateral flow.

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A Brief History of Brazilian Aeronautics

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Abstract. *The history of aeronautics is the history of the technological development spiced by the enterprising spirit of aviation pioneers. The flight revolution was largely a product of technology and not so much of science. Its practitioners followed the tradition of the craftsmen and technicians who, awakened by the experimental method of Sir Francis Bacon and others, were the proto-engineers of the great expansion of technology and engineering that happened from the time of the Industrial Revolution onwards. Its first great accomplishment was the re-invention of lighter-than-air flight in 1783. Some time before the Brazilian Jesuit Bartolomeu de Gusmão make flew an unmanned small balloon in Portugal. By the mid-1790's, the balloon had already been turned to practical benefit, as an observation system; it appeared as a scientific lifting platform shortly afterwards. The quest for steerable flight led to the creation of practical, small airships by the end of the 19th century, and the larger rigid airship appeared at the beginning of the 20th century, almost simultaneously with the appearance of the airplane. An overview of milestone events that marked the history of aeronautics worldwide is presented in its early days. The major achievements by the Brazilian Santos-Dumont are also described and analyzed as well as the major events in the Brazilian Aeronautics history. The article finishes reporting the beginning of EMBRAER activities focusing on the improved twin-engined aircraft Bandeirante, which was originally designed at Aerospace Technical Center (CTA) and ultimately led to the creation of that company.*

Keywords*.Aircraft Desin,; History of Aeronautics,*

1. Flight is in the air

1.1 The crusade for the first flight

Comparing to the civilization history, but the history of aviation is quite recent, only about a century old. The camera film was created in 1825. In 1895, a motion picture was shown for the first time before an audience in Berlin. Likewise, early developments in aviation are well recorded. Because the history of the aerostat started long before that of the airplane, it is less known. Ancient inscriptions and texts indicate that the Chinese used hot air balloons and gigantic kites before the Christian era in order to keep it under surveillance the battlefield. The Mongols used illuminated kites to communicate during the Battle of Legnica against the Poles in 1241 A.D. Much later, Portugal became one of the most powerful nations in the world. That came about thanks to the Knights Templar, which was one of the most famous Christian military orders. Under the influence of the French King Philip, *le Beau*, the Pope Clement V declared an internal crusade against them. On Friday, October 13, 1307 (a date possibly linked to the origin of the Friday the 13th legend), Philip had all French Templars simultaneously arrested, charged with numerous heresies, and tortured by French authorities nominally under the Inquisition until they allegedly confessed. This action released Philip from his obligation to repay huge loans from the Templars and justified his looting of Templar treasuries. In 1312 due to the public opinion and scandal, and under pressure from King Philip (who had been responsible for maneuvering Pope Clement V into the Vatican), Clement officially disbanded the Order at the Council of Vienna. Even though all their lands were supposed to be turned over to the Hospitallers, Phillip retained a great deal of the Templar assets in France. Some other European leaders followed suit in an effort to reduce the amount of Church-owned lands and property. In 1314 three Templar leaders, including Grand Master Jacques De Molay, Hugh De Perault and Godfrey De Goneville were burned alive at the stake by French authorities after publicly renouncing any guilt. Remaining Templars around Europe, having been arrested and tried under the Papal investigation, were either absorbed into other military orders such as the Order of Christ and the Knights Hospitaller or contemplative Benedictine or Augustinian orders. In Portugal they found refuge under the Order of Christ. The Templars brought to Portugal treasures, much of the knowledge of ancient civilizations, and naval technology from the Arab people. Brazilian Jesuit Bartholomeu de Gusmão (**Fig. 1**), born in Brazil to Portuguese parents, adopted a religious career and moved to Portugal when he was aged 15. By reading antique writings possibly brought to Portugal by Templars, he rediscovered the principle of the hot air balloon. In August 1709 Gusmão built a small and unmanned balloon and performed a demonstration at the court of King Dom João V. There are reports that Gusmao built an unmanned larger balloon that freely ascended outdoors some time later. Bartolomeu de Gusmão proceeded with his experiments with larger balloons and legend has it that eventually he himself flew a balloon which was launched from St. Jorge Castle, on top of one of Lisbon's seven hills, covered 1 km, and crashed in Terreiro do Paço. However, there is no evidence that this actually happened. Later Gusmão was pursued by the Inquisition the and left Portugal. Before leaving the country, he gave his brother several drawings of his balloons. Later his brother worked at Portugal's Embassy in Paris and established some contacts to José de Barros, a scientist close to the Montgolfier brothers, the first people to construct a balloon that performed a recorded manned flight in history. This flight took place in France in 1783 with Jean Pilâtre de Rozier and the Marquis d'Arlandes on board.

Fig. 1 – Bartholomeu de Gusmao rediscovered the hot air balloon. It is highly probable that he exercised great influence on Montgolfier's work.

From the flights with Montgolfier balloons on, ballooning became a rage. In 1785 Jean-Pierre Blanchard and John Jeffriesf departed from England on a balloon and crossed the English Channel. In 1794, France opened a ballooning school. France used two balloon corps in the battles of Maubeuge and Fleurus and in the Mainz siege in the following year. In July of 1849 Austrian troops used balloons for the first time to drop bombs on Venice.

English aeronaut Charles Green (1785-1870) used a coal gas-filled balloon formerly known as the 'Royal Vauxhall' for his most famous flight from London to Nassau in Germany in 1836. It was on this voyage, along with passengers Robert Holland MP and Thomas Monck Mason that Green successfully completed the world's longest flight, covering an estimated 770 km in 18 hours. After achieving this feat, Green had an endless supply of patrons eager to ascent in the famous balloon.

1.2 A better move

In 1852 the Frenchman Henri Giffard was the first to fly an airship, which was fitted with steam engines and propellers (**Fig. 2**). From then on, numerous crafts followed, including Paul Haelein's craft in 1872 (**Fig. 2**) and Charles Ritchel's in 1878. Paul Haelein from Germany was the first to use internal combustion engines on an airship. Hydrogen, used as fuel to lift the airship, was stored in only one tank. In the United States, Charles Ritchel made demonstrations of a lighter-than-air craft built with impermeable fabric and a tubular structure with room for the pilot and an engine, and managed to sell five units of his flying machine. Several other airships produced significant innovations before the turn of the century.

In 1884 the brothers Albert and Gaston Tissandier of France designed and constructed the first airship powered by electricity. The current was supplied by 24 bichromate of potash cells to a Siemens 1.5 hp (1.1 kW) at 180 revolutions per minute. The engine drove a large two-bladed pusher propeller through reduction gearing. The speed achieved in calm air was still only 4.8 km/h since the ratio of power to weight was no better than Giffard's had been.

Charles Renard and Arthur C. Krebs, inventors and military officers in the French Army Corps of Engineers, built an elongated balloon, *La France* (**Fig. 2**), which was a vast improvement over earlier models in 1884. *La France* was the first airship that could return to its starting point in a light wind. It was 50.3 m long, its maximum diameter was 8.2 m, and it had a capacity of 1,869 m^3. Like the Tissandiers' airship, an electric, battery-powered motor propelled *La France*, but this one produced 7.5 hp (5.6 kW). This motor was later replaced with one that produced 8.5 hp (6.3 kW). A long and slender car consisting of a silk-covered bamboo framework lined with canvas hung below the balloon. The car, which was 33 m long, 1.4 m wide, 1.8 m deep, housed the lightweight batteries and the motor. The motor drove a four-bladed wooden tractor propeller that was 7 m in diameter, but which could be inclined upwards when landing to avoid damage to the blades. Renard also provided a rudder and elevator, ballonnets, a sliding weight to compensate for any shift in the center of gravity, and a heavy guide rope to assist in landing. The first flight of *La France* took place on August 9, 1884. Renard and Krebs landed successfully at the parade ground where they had begun - a flight of only 8 km and 23 minutes but one during which they had been in control throughout. During 1884 and 1885 *La France* made seven flights. Although her batteries limited her flying range, it was demonstrated that controlled flight was possible if the airship had a sufficiently powerful lightweight engine.

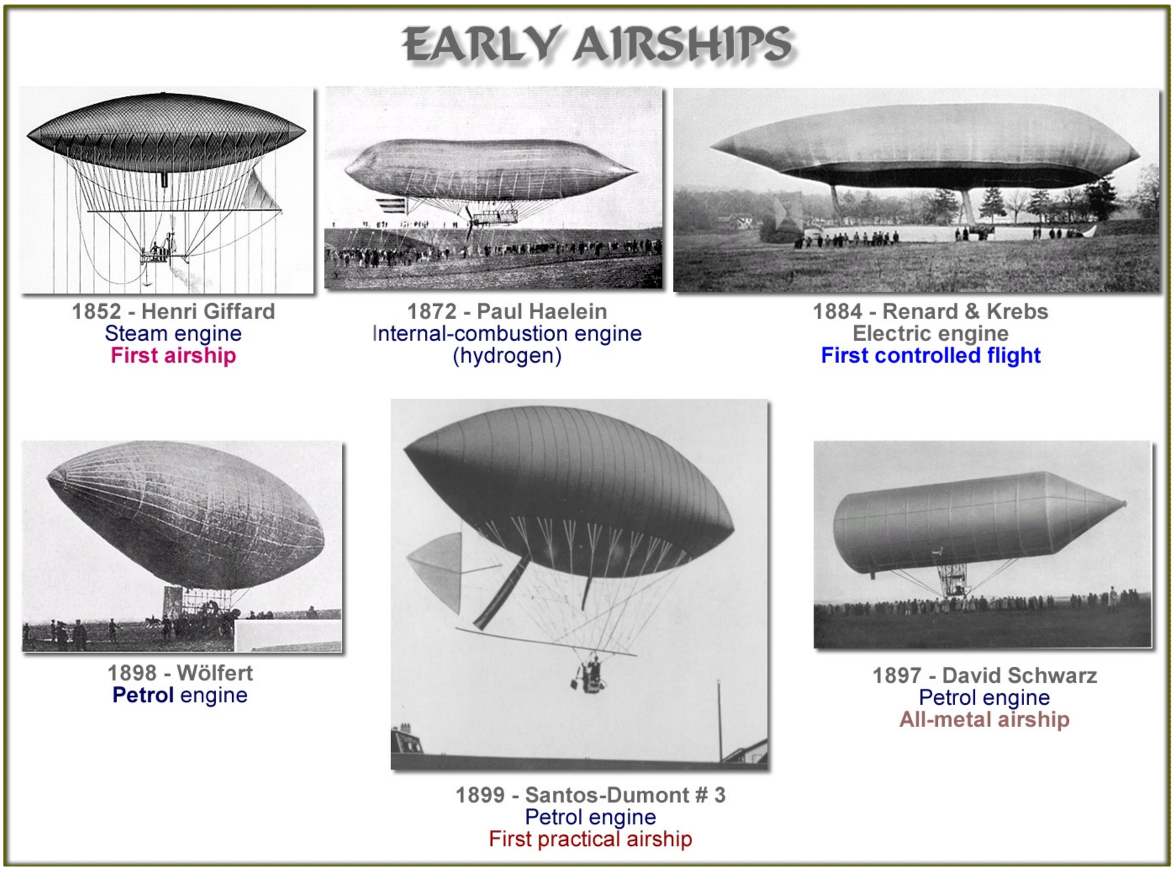

Fig.2 – Some early airships of nineteenth century.

The first airship equipped with a petrol engine was built by Karl Wölfert in Germany (**Fig. 2**). In 1896, he constructed a dirigible pointedly named *Deutschland* (Germany). The gondola was directly connected to the hull and an 8-hp Daimler engine powered the aircraft, which flew for the first time on August 10, 1898 in Cannstatt, close to the city of Stuttgart. In 1897, the airship caught fire during a flight in Tempelhoff. Wölfert and his mechanic died in the accident. Escaping hydrogen from the envelope had probably come into contact with the hot exhaust gases from the engine. They were the first victims of power-driven aviation. Future designers would avoid placing the petrol engine so near the flammable hydrogen balloon.

Austrian engineer David Schwarz was also attempting to harness the petrol engine to dirigible flight. His airship was highly unusual and ahead of its time in being made of sheet aluminum, an eight thousandth of an inch thick, which was supported internally by an aluminum frame braced with wires (**Fig. 2**). The airship was 47.5 m long and had a capacity of 3,700 m^3. Power was provided by a 12-hp Daimler engine, driving four propellers, two of which were for steering and two for propulsion. Schwarz's mechanic had the dubious honor of testing his employer's novel brainchild. The airship made its maiden voyage from Templehof, Berlin, on 3 November 1897. It made several successful circles, but then started to descend rapidly before it struck the ground and broke up. This time however the pilot was able to walk away, unhurt.

1.3 Santos-Dumont constructs the first practical airship

Santos-Dumont was born in Brazil on July 20, 1873. Dumont´s father declared his majority when he turned 18. He inherited from his father hundreds of *Contos de Réis*, equivalent today to some tens of millions of dollar. The wealthy, talented and open-minded young Dumont moved to Paris to pursue the studies of physics, chemistry, mechanics and electricity to achieve his dream of flying. He designed, built, and flew some balloons before developing the first practical airship. He also performed the first fully public flight of an airplane in the world, in Paris in October of 1906 (In comparison, the secretive Wright brothers did not make any public flights until 1908). Many historians considered Dumont a scientific genius. Actually he was a master of technology integration into aircraft configuration. In the circles in which he moved there were a lot of aviation pioneers. Dumont discussed with his friends aeronautical matters and everyone benefited of this friendly atmosphere.

The Balloon Brésil was the first one designed and built by Dumont and was ahead of its time. He employed in its construction Japanese silk resulting in a much smaller and lighter balloon compared to the existing ones with the same payload. The common sense at that time advised the use of Chinese silk but Dumont correctly calculated that Japanese silk would enable a lighter balloon.

After his brief experiments with balloons, the Brazilian Alberto Santos-Dumont released his first dirigible in 1898, the year after David Schwarz's crash. He christened it Santos-Dumont No.1. It was made of lightweight Japanese silk, had a capacity of 186 m^3 and was powered by a 3.5-hp internal combustion engine. In common with many other quirky Santos-Dumont designs, the No.1 was no bigger than was strictly necessary to lift its pilot. Santos-Dumont did not even have room to sit down in the tiny wicker basket. After a takeoff attempt, Dumont's no. 1 crashed on September 18, 1898. The airship hit the trees of Jardin D'Acclimatation in Bois de Boulogne and was extensively damaged. He repaired the airship and took off again a couple of days later. Using the incidence-changing mechanism he had designed, he was able to reach a height of 400 m. At the highest altitude attained by Dumont, the pressure drop accounted by hydrogen leakage, which was caused by the porosity of the hull, could not be compensated by the Dumont's mechanism anymore. The graceful dirigible was out of control and began to fall. With serenity and self-control, Dumont shouted out for some boys below to catch the hanging rope and maneuvered the airship against the wind. The landing was then almost perfect. In May 1889, the no. 2 (**Fig. 3**) was ready for flight. Dumont's second airship was strongly based on the no. 1 design. Despite of rain, windy weather and low temperature he decided to fly. Short after takeoff the airship hit some trees and broke into two pieces. The low air temperature increased the hydrogen concentration and the pump was not able to avoid the hull to lose its rigidity. Winds then threw the airship against the trees.

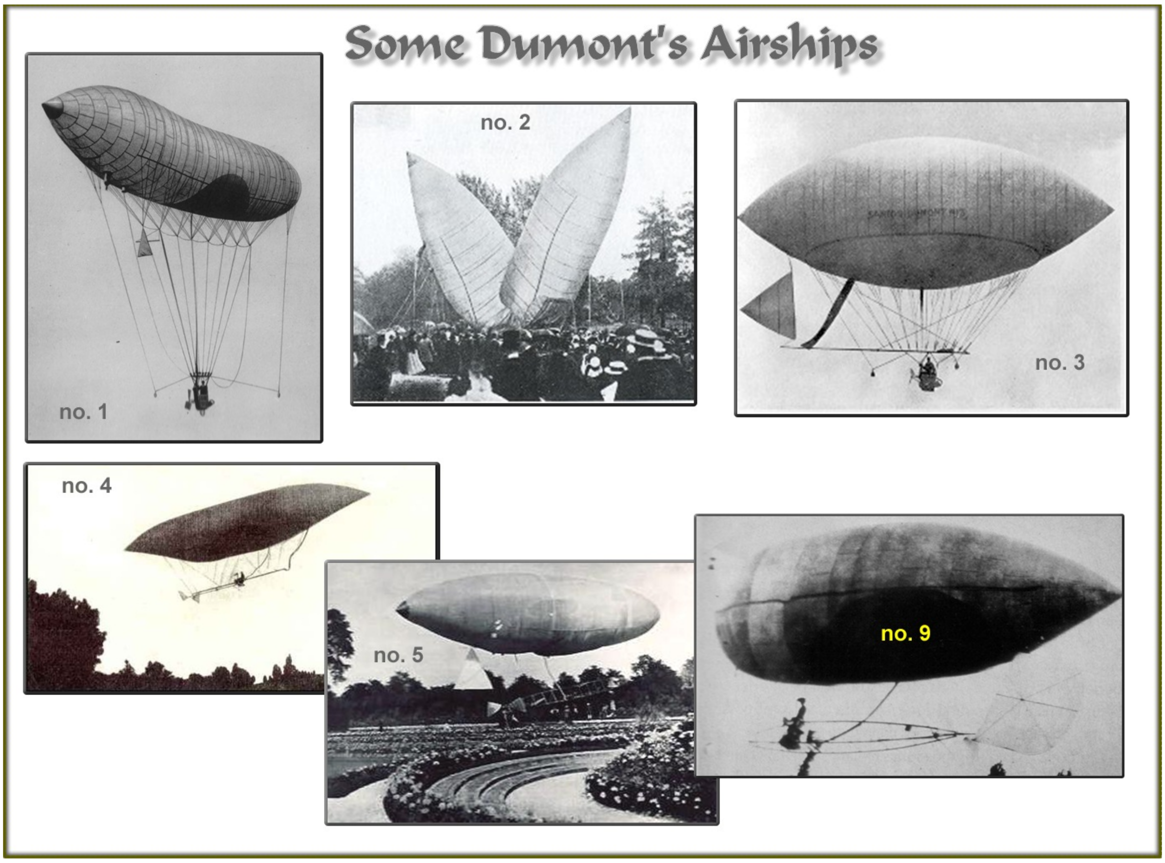

Fig. 3 – Some airships designed and constructed by Santos-Dumont.

Dumont employed illumination gas instead of expensive hydrogen for lifting the no. 2 airship. The main idea behind this was to design a low-cost aircraft, which could be serially manufactured to be employed as general transport. Although Dumont was a rich person, his intention was to develop aircraft thinking in mass transportation. Many analysts erroneously consider him just as a sportsman.

On November 13, 1889, Dumont finally performed a controlled flight with his no. 3 airship (**Fig. 3**), which was lifted by hydrogen and powered by an internal combustion engine. **T**he determined Brazilian modified his design so that envelope failure should be almost impossible. This time a long sausage shape was rejected in favor of an elliptical envelope, similar to the one Giffard and his friend Tissandier (**Fig, 4**) had used before. Since it was thickest in the middle of its length, it should be unable to fold up on itself.

Millionaire, Henri Deutsch de la Meurthe, established the Deutsch de la Meurthe Prize in 1900 to be granted the first person to fly around the Eiffel Tower, leaving from and returning to the Saint Cloud field within 30 minutes. The entire city of Paris watched as Santos-Dumont performed this aviation milestone in October 1901, piloting his airship number 6 (**Fig. 5**).

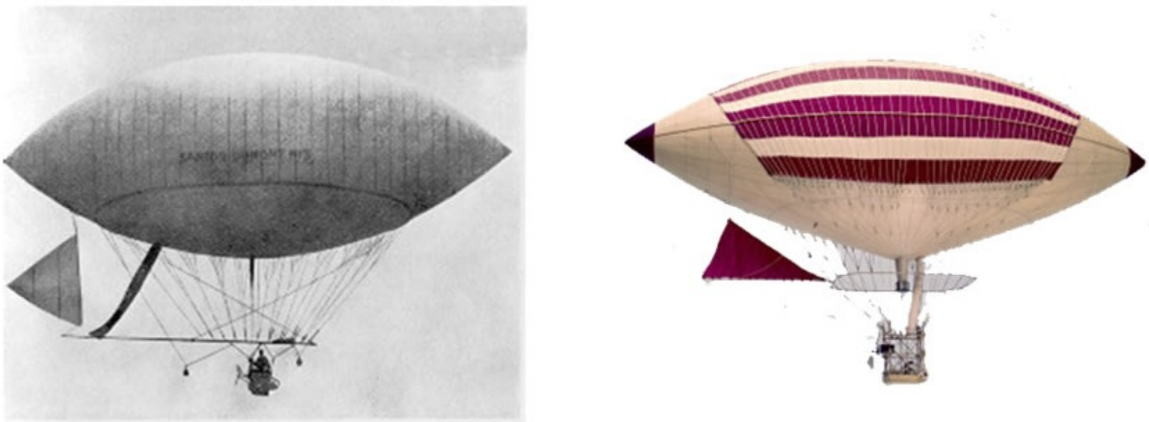

Fig. 4 – Santos-Dumont no. 3 was very similar in shape when compared to the electric-powered Tissandier's airship.

Fig. 5 – *Left.* No. 5 suffered from gas leakage after contouring the Eiffel Tower. This picture is erroneously misinterpreted by many historians - they refer that the airship in the picture is the no. 6. *Right.* The no. 6 in the trajectory to win the Deutsch de la Meurthe Prize.

Dumont envisioned a future in which air transportation would have an important role. No. 16 Omnibus, Dumont's largest design, was conceived with passenger transportation in mind. This dream came true as early as 1910 with regular airship flights by German DELAG, the first airline in the world. Later on, the Zeppelin Company became famous for using airships to carry passengers overseas. On the July 2, 1900 LZ 1, the first Zeppelin airship, made its maiden flight. It was only 18 minutes in the air and carried five passengers. The cloth-covered dirigible, which was the prototype of many subsequent models, had an aluminum structure, seventeen hydrogen containers for the lifting gas storage, and two 15-hp Daimler internal combustion engines, each turning two propellers. After two further flights, which took place on October 17, and 21, 1900, it was scrapped. In 1905, Zeppelin could build his second airship. The LZ 2 incorporated three major improvements: lighter and more powerful engines; more accurate commands; and stronger structure. However, by the second test flight in 1906, one of the engines malfunctioned and the airship must to proceed to an emergency landing. Afterwards a thunderstorm caught the aircraft and destroyed it.

During the first years of the 20th century, Dumont was the only one who was able to fly in a controlled fashion. Emmanuel Aimé once declared "Among all airship designs, openly or secretly studied in the last few years, the one by Santos-Dumont is the only one capable of flying in the free atmosphere. Say what you may, but there are no airships in the world, there is only one and you have to come to Paris in order to see it." Aiming the testing of an Aimé's invention, Dumont performed three flights with the balloon Fatum. Aimé intended with its invention to provide enhanced vertical control saving at the same time gas and ballast.

2. Spreading Wings

2.1 Full steam ahead

Experimental development was performed side-by-side with theoretical work carried out by scientists and researchers. Thus, fluid mechanics had been evolving a long time. In 1738, Daniel Bernoulli published his findings on the relationship between pressure and gas velocity. Bernoulli's assistant, Leonard Euler, published some articles in 1750 containing his famous equations on the behavior of compressible fluids. Italian mathematician Joseph Lagrange and French mathematician Pierre-Simon Laplace studied Euler's findings and tried to solve his equations. In 1788, Lagrange introduced a new model for fluid flow as well as new equations for calculating velocity and pressure. In 1789, Laplace developed an equation that would help solve Euler's equations. It is still used in modern aerodynamics and physics. Laplace also successfully calculated the speed of sound. In addition to these theoretical advancements, experiments in aerodynamics were also producing more practical results. In 1732, the French chemist Henri Pitot invented the Pitot tube, a device that enables the calculation of velocity at a point in a flowing fluid. This would help explain the behavior of fluid flow. The English engineer Benjamin Robins performed experiments in 1746 using a whirling arm device and a pendulum to measure drag at low and high speeds. In 1759, the English engineer John Smeaton also used a whirling arm device to measure the drag exerted on a surface by moving air. He proposed the equation $D = kSV^2$, where D is the drag, S is the surface area, V is the air velocity, and k is a constant, which Smeaton claimed was necessary in the equation. This constant became known as Smeaton's coefficient, and the value of this constant was debated for years. Those making the first attempts at flight, including the Wright brothers, used this coefficient. The French scientist Jean-Charles Borda published the results of his own whirling arm experiments in 1763. Borda verified and proposed modifications to current aerodynamic theories and was able to show the effect that the movement of one object had on another nearby object. The Navier-Stokes equations, considered the most complete mathematical model of fluid flow, were written in the beginning of the 19^{th} century. However, this system of equations was solved only halfway through the 20^{th} century. For this reason, aviation pioneers largely used experimentation and employed less complex theoretical models in order to achieve their goals. As of the mid 19th century two new trends emerged based on the steam engine: the race to fly a lighter-than-air airship with engines and directional control, and the development of fixed-wing aircraft. Over time, the airplane began to take on a familiar shape.

In 1799, twenty-six year old George Cayley (1773–1857) sketched what it is now recognized as the familiar conventional configuration of an airplane: a cambered wing having dihedral; an aft vertical tail; and an aft horizontal tail. Cayley's choice for the airfoil was based on aerodynamical characteristics of airfoils tested by him and his predecessors using a whirling arm apparatus. Cayley himself invented dihedral as a means for maintaining equilibrium in roll. The vertical tail provided directional stability, like the feathers on an arrow, and in Cayley's view, would also be used for steering, as a boat's rudder serves. By analogy, the horizontal tail gave stability in pitch. It turned out later that Cayley was half right on both counts. Cayley did not formally apply Newton's laws for translational and rotational motions to the airplane. He produced no mathematical descriptions for the motions of an aircraft and therefore has no quantitative basis for designing his flying machines. But he had things right at the level he worked. Already with his first efforts he established the principle that he later explained thoroughly in a series of papers: The means of producing lift to compensate weight must be distinct from the means of generating thrust; a revolutionary idea at the time. He properly shifted attention to artificial flight from simple imitation of birds to development of fixed-wing aircraft.

As of 1891, the German Otto Lilienthal performed about 2000 glider flights. Both Lilienthal and Cayley wrote books and articles about light theory that influenced the work of the pioneers that followed. The English mechanic and lace-machinery operator William Samuel Henson was one of them. He designed an airplane called *Aerial Steam Carriage* (**Fig. 6**) in 1842. He applied for a patent in London in November 1942. It was granted in March 28, 1843. In text of his patent, he wrote that the purpose of his creation was *the transport of cargo and passenger from place to place*. This patent was the first one issued for an airplane in history. Henson's airplane configuration was comprised of landing gear, tail surfaces, and engines mounted behind the wing and the passengers would be transported in an enclosed fuselage. Two counter-rotating six-bladed propellers should drive the airplane. However, the *Aerial Carriage* was never built and never flown. In society with John Stringfellow, Henson formed the *Aerial Transit Company* with financial banking of such men as D. E. Columbine; John Marriott, a journalist whose value was the he “knew a member of Parliament”; and a Mr. Roebuck, who was expected to promote a bill in Parliament for a shareholders company to operate an *Aerial Steam Carriage*[6]. Henson and Stringfellow engaged in model testing in order to become true their airplane. In 1843, they obtained the help of Joe Chapman, a mathematician, who also had a whirling arm device. Chapman made more than 2000 recorded aerodynamic experiments on the whirling arm for Henson and Stringfellow. This led to an airplane with a wing with a span of 6 m and a area of 5.84 m^2 powered by a small steam engine designed primarily by Henson but improved by Stringfellow. Some unsuccessful flight attempts were made with this type. The machine was not able to get airborne after being launched by a catapult system. Lack of suitable power and techniques for the construction of lightweight structures were the reasons for the *Aerial Steam Carriage* failure. Henson migrated to the United States in 1848.

Other many flight attempts occurred with aircraft powered by steam- and electric-engines. These flights were unsuccessful because that kinds of engines present high weight-to-power ratio. Only after the internal combustion engine was improved did flying with a heavier-than-air aircraft become possible.

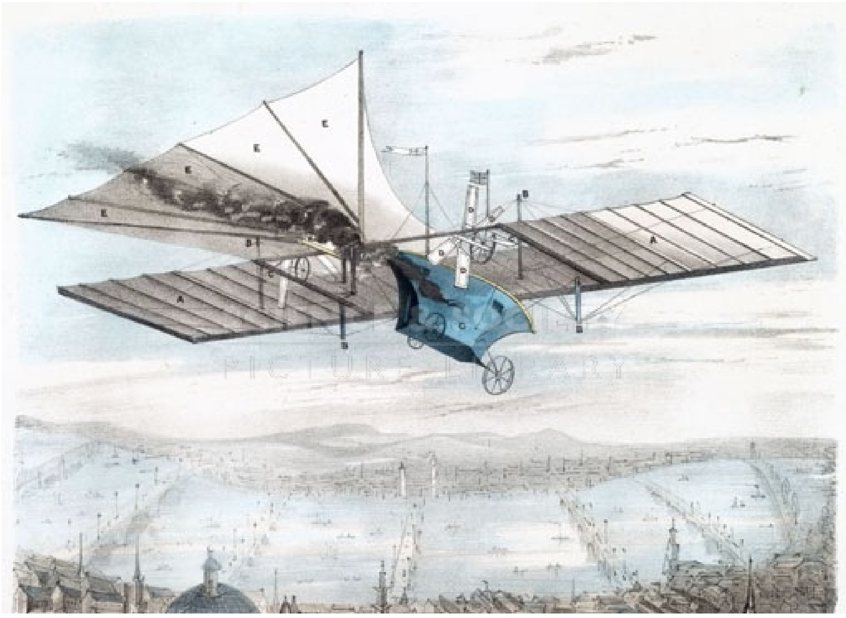

Fig. 6 – Illustration of the Aerial Steam Carriage of Samuel Henson.

2.2 Sense and sensibility

Dumont attended mechanic, aeronautic, and naval construction classes at the University of Bristol, England. With his taste for experiments, Dumont was directly influenced by the Industrial Revolution. Several of his friends, including Louis Blériot, Henri Farman, and Gabriel Voisin were baffled by Dumont's ability to rapidly put his ideas into practice. Dumont was not a theoretician or a scientist, but he superbly integrated the technologies at his disposal at that time. In addition, he improved existing technology in many aspects when, for example, lubrication of opposed-cylinders engines. He also invented devices and mechanisms to improve airship stability and maneuverability.

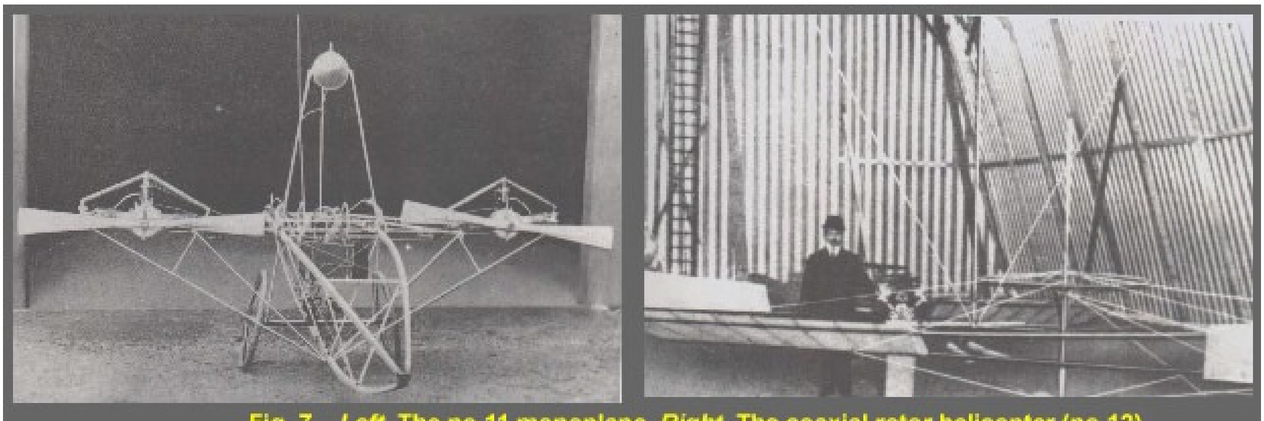

Fig. 7 – *Left.* The no.11 monoplane. *Right.* The coaxial rotor helicopter (no.12).

Contrary to many analysts usually affirm, Dumont had been thinking about a heavier-than-air aircraft for a long time[14]. He initially considered a huge airplane based on Cayley's ideas[12]. However, he constructed a much smaller monoplane machine (**Fig. 7**) similar to his Demoiselle, which came later. Dumont also constructed a counter-rotating dual rotor helicopter (**Fig. 7**) but soon he was aware of the difficulties posed by a vertical takeoff concerning the required higher power-to-weight ratio. In this meantime, Dumont was convinced by the Voisin brothers to switch to a biplane configuration shaped like a square kite called Hargrave box. In 1905, The Voisin brothers ran a glider manufacturing business in Paris. This configuration had been successfully employed in their glider designs (**Fig. 8**). During some trials in the Seine River, Dumont perceived that the Antoinette boat engine, which was employed to bring the glider airborne, could be fitted in a heavier-than-air machine (**Fig. 8**). On this way, the 14*Bis* was conceived.

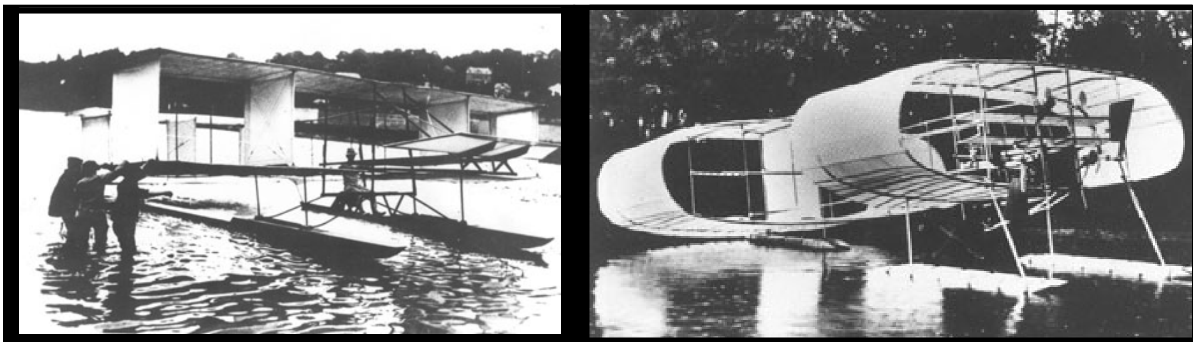

Fig. 8 – *Left*. Voisin-Blériot glider based on Hargrave box configuration (1905). Santos-Dumont is the one sitting in the middle of the aircraft. *Right*. This machine was built by Gabriel Voison for Louis Blériot from Blériot's designs in 1906. It began as a glider and was later fitted with an engine and propellers. When Voison test flew it, it sank in the Seine River.

On November 12, 1894 Lawrence Hargrave, the Australian inventor of the box kite, linked four of his kites together, added a sling seat, and flew 16 feet. By demonstrating to a skeptical public that it was possible to build a safe and stable flying machine, Hargrave opened the door to other inventors and pioneers. The Hargrave-designed box kite, with its improved lift-to-drag ratio, was to provide the theoretical wing model that allowed the development of the first generation of European and American airplanes.

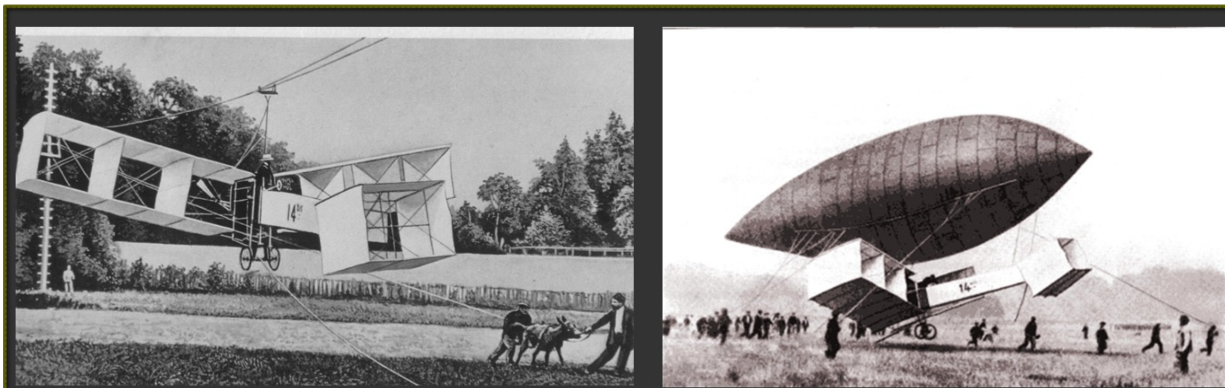

Fig. 9 – Trials with 14Bis before the flight of October 1906.

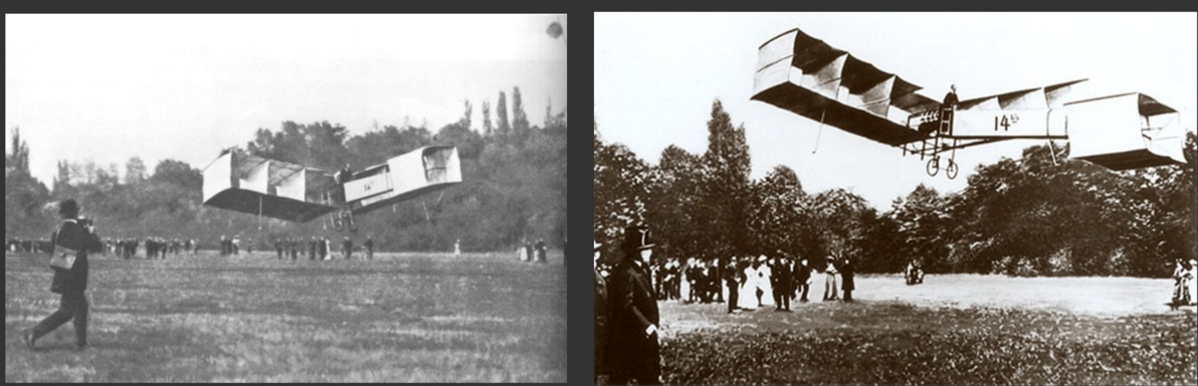

Fig. 10– Flights with 14Bis in October (Left) and November (Right) 1906.

Dumont properly did not follow entirely the Hargrave box kite concept. He transformed a pair of wings incorporating a control surfaces box in a canard configuration. The l4*Bis* was constructed at Neuilly-St. James on the outskirts of Paris and was tested exhaustively (**Fig. 9**). At first, his airship No. 14 served as a support platform for evaluating the stability of the airplane and, for this reason, it was called 14*Bis* (encore). Thus Dumont also invented the flight test. Finally, Dumont performed a few flights with his biplane and in France. On October 23, 1906, he covered a distance of about 60 meters flying 2-3 m above ground. He achieved success after increasing the engine power to 50 hp. The 14*Bis* took off by its own means before a huge crowd, especially the Aero Club of France commission, who attended for the occasion. On November 12, Dumont performed longer flights with the 14*Bis*.

Some months earlier, on August 21, 1906, Santos-Dumont made his first attempt to fly. He did not succeed, since the 14*Bis* was underpowered. On September 13th, with a reengined 14*Bis* (now with a 50 hp power engine which he obtained through Louis Bréguet), Santos Dumont made the first flight of 7 or 13 m (according to different accounts) above the ground, which ended with a violent landing, damaging the propeller and landing gear. On October 23th, 1906 his 14Bis biplane finally flew a distance of 60 meters at a height of 2 to 3 meters during a seven-sec-long flight (**Fig. 10**). Santos Dumont won the 3,000 Francs Prize Archdeacon, instituted in July 1906 by the American Ernest Archdeacon, to honor the first flyer to achieve a level flight of at least 25 m. Before his next flight Santos Dumont modified the 14*Bis* by the addition of large octagonal ailerons, to provide some roll control. Although ailerons had been used in sailplanes before, Dumont pioneered their application for airplanes. Since he already had his hands busy with the rudder and elevator controls (and could not use peddles as he was standing), he operated the commands via a harness attached to his chest. If he wanted to roll right he would lean to his right, and vice versa. With the modified aircraft, he was back again on trials on November 12th. This time the Brazilian was not alone. Blériot and Gabriel Voisin had built a flying machine aiming to win the prize. Their machine presented an elliptical wing and a pair of trapezoidal ones. After some takeoff attempts, their flying machine was damaged. Dumont then initiated the takeoff run but damaged the landing gear. After repairing the 14*Bis*, Dumont made six increasingly successful flights. One of these flights was 21.4-s long within a 220 m path at a height of 6 m, attained after taking off against the wind (**Fig. 10**).

2.3 Traveling far

Santos-Dumont had shown the World that the dream of long-range powered flight could be a reality. During 1907 many aviation enthusiasts and experimenters tried to build on his achievement. Few of them, however, met with much success. Among them were Adolf de Pischof, Louis Blériot, and Romanian Trajan Vuia. Meanwhile Paul Cornu and the Breguet brothers experimented with helicopter designs. In Britain, Horatio Philips got (briefly) airborne in a machine with four sets of wings, Samuel Cody began construction of a biplane for the Army, and John William Dunne was commissioned by the Government to design an airplane in secrecy. The most successful aircraft of the year was by far and away the one made by the brothers Charles and Gabriel Voisin, now with a plant for airplane manufacturing (**Fig. 11**). With a biplane elevator at the front was based on the Hargrave boxkite construction, and carried a huge square tail assembly at the rear. Power was provided by the 50-hp Antoinette engine. It was a crude and heavy machine with no control in roll at all, but it was capable of staying in the air for several seconds at a time, and on this basis the brothers set up a workshop to manufacture it. In the summer of 1907 their third production machine was ordered by Henry Farman.

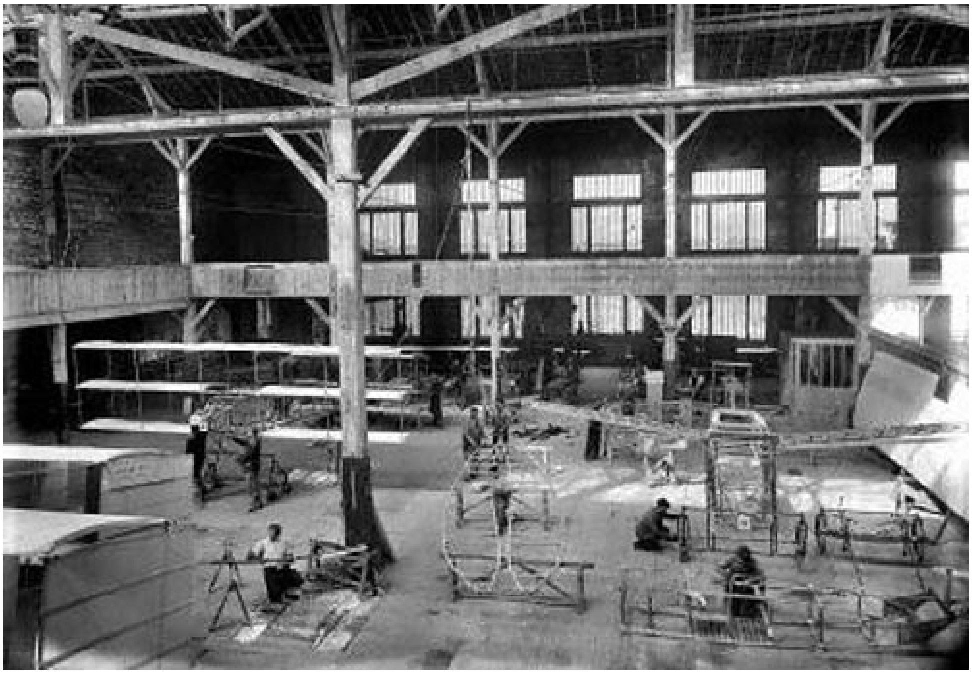

Fig. 11 – General view of Voisin brothers' airplane manufacturing plant (1908).

Henry Farman was born in 1873, the son of a respected English newspaper correspondent working in Paris. Henry trained as a painter at the École des Beaux Artes, but quickly become obsessed not with painting, but with the new mechanical inventions that were rapidly appearing at the end of the nineteenth century. Since the Farmans were well-off he was able to pursue this interest as an amateur sportsman. Farman had a natural flair for getting the *feel* of a piece of machinery, and enjoyed considerable success. In the 1890s, he became a championship cyclist, and at the turn of the century he discovered motor racing. Driving Panhard cars he came fifth in the Paris-Berlin road race of 1901, and then won the Paris-Vienna in 1902. With his mechanic he covered the 615 miles to the Austrian capital in just 16 hours along unmade roads. Farman himself became a casualty of the sport when he was involved in a serious accident. He fully recovered, but the experience destroyed his enthusiasm for cars. Nevertheless his fascination with machinery endured. He was aware of the Voisin float-glider experiments on the Seine during 1905/06, and he had flown in balloons before with his brother, Richard. When the Voisins began to produce a powered airplane for sale in 1907 he was one of their first customers. He made his first flight at the end of September and, displaying his usual sure feel for machines, he was soon able to stay in the air longer than anyone else. On 26 October he flew for 771 m at Issy. For this flight he won a cup sponsored by Ernest Archdeacon of the Aéro-Club. By early November, Farman was coaxing turns out of the Voisin, despite it being built without any roll control. This meant that all turns were a delicate skid round on rudder alone. If the outside wing picked up too much airspeed it would rise, and if the turn was persisted in, the plane would be in danger of side-slipping into the ground lower wing first. Farman incorporated a number of modifications of his own to the Voisin during the autumn, including a reduction in the size of the tail surfaces, removing one of the forward elevators, and rigging a slight dihedral angle into the wings. Thus the Voisin-Farman I became the Voisin-Farman I-bis. By now it was clear to members of the Aéro-Club that Farman would soon attempt to win the last and largest Archdeacon prize, the so-called *Grand Prix of Aviation*. This comprised a purse of 50,000 francs (of which half had been contributed by oil magnate Henri Deutsch de la Meurthe), for the first aviator who could fly to a marker 500 m. from his take-off point and return without touching the ground. Farman performed a test flight on November 9 without observers, but then the weather deteriorated. His record attempt was finally made early in the new year, on 13 January 1908. A pole was set up on the frosty parade ground at Issy by Aéro-Club officials and a finishing line marked by flags 500 m. away. In contrast to Santos-Dumont's flights a year or so earlier, there were no large crowds present - only a knot of fellow enthusiasts in overcoats. Farman took off, crossed the line at low altitude and began a wide turn with the pole at its center. Gradually he wavered back up towards the spectators by the flags. One minute, 28 seconds after he took-off, he flew by the line to their jubilant cheers of congratulation. Due to his wide, flat turn he had probably covered about 1500 m. in all (about a mile). This was by far the longest European flight to date.

Fig. 12 – The Delagrange-Voisin airplane.

After receiving the 50,000 francs because he won the contest, Henry Farman make further modifications to his Voisin in preparation for a new flying season. In March 1908, he recovered the machine in rubberized fabric and changed the engine for a 50-hp Renault. The Voisin-Farman I-bis thus became the Henri Farman I-bis. The new engine did not last long and he installed back the Antoinette one. However, Farman's constant tinkering with his plane show how confidently he had grasped the essentials of aeronautics. During the summer he added side-curtains to the wings, to make them true boxkites, and importantly put in ailerons of his own design so that the machine could be banked. On May 28, 1908 Farman took the first passenger in Europe into the air. Appropriately enough it was Ernest Archdeacon, the man who had done so much to encourage aviation in France since 1903.

The only other prominent aviator during this period was Léon Delagrange who, like Farman, had purchased a standard Voisin in 1907 (**Fig. 12**). However he was less technically-minded than Henry and had made only a few modifications to the basic design. Gabriel Voisin remarked that in contrast to Farman, Delagrange *was not the sporting type* and knew nothing about running an engine. Nevertheless a sporting rivalry seems to have developed between the two fliers. In the summer of 1908 Delagrange went south to Italy to demonstrate the art of flying while Farman went north to Belgium. On 23 June, Delagrange set an endurance record of 18 minutes, 30 seconds at Milan: Farman retaliated with 20 minutes, 20 seconds at Ghent, on 6 July. On 6 September Delagrange flew for 25km (15 miles) at Issy: Farman bested that with 40km (25 miles) at Champ de Chalons on 2 October. Finally, Farman made the logical next step of flying between two places, rather than simply making measured circuits over the safety of an aerodrome. On 30 October 1908, he flew the 27 km from his camp at Bouy to the cavalry ground at Rheims in just under 20 minutes.

The Voisins had built an airplane for Henry Kpferer and then one for Léon Delegrange in which Gabriel Voisin achieved flight in 1907; they then built an airplane for Henry Farman which was the first to fly a kilometer circuit; Voisin then built another for Farman, but instead sold it to J.T.C Moore-Brabazon. This infuriated Farman so much that he established his own company to compete with Voisin. The first aircraft Farman produced was the Type III of 1909. Later Farman formed the Farman Airlines, which operated the famous Farman Goliath airliner in the 20s.

2.4 All things are changing, and we are changing with them

According to their own report[7], on December 17th, 1903, the Wright brothers took to skies on their Flyer I biplane. This machine was equipped with two propellers, which were driven by a single 12-hp four-cylinder reciprocating engine. Many historians recognize this flight as the first manned flight. The following Flyer II was fitted with a 16-hp engine and had a takeoff weight of 408 kg that resulted in a weight-to-power ratio of 25.5 kg/hp. About 30 reporters showed up at Huffman Prairie on May 23, 1904. However, the Wrights could not get the Flyer II motor to run properly, and everyone went home disappointed. A handful came back on May 26, but the Wrights were only able to manage a flight of about 8 m. Indeed, Flyer II was not able to takeoff if strong wind conditions were not present. However, there are some photographs of alleged flights with Flyer III in Huffman Prairie in 1905. Flyer III was fitted with a 20-hp water-cooled engine and presented a takeoff weight of 388 kg. Even flights that covered a distance of astonishing 12 miles were said to be performed (**Fig. 13**) with this type. Surprisingly the Wright brothers did not fly during 1906 and 1907 and many enthusiasts say that they were busy applying for patents.

In 1901 the Frenchman Ferdinand Ferber, heard of the Wright brothers work from Octave Chanute. He begins to correspond with the brothers. Two years later Ferber built a copy of a Wright glider and fitted an engine to it. He attempted to fly the machine tethered to a crane but without success. In December 1905, Ferber published the letters he had received from the Wright brothers. The letters contained some allegations that the two Americans had performed 18-miles flights in a closed circuit. Ferber had a special interest in disclosing such kind of information: he intended to convince the French Army to purchase the brothers' creation. Most French people interested in aviation did not believe that the Americans had obtained success in flying a powered machine. Archadecon challenged the Wright brothers to come to France to display their aircraft there. He even offered cash for that. However, he even got a single replay form the Americans.

Anyway, the Wright brothers were unable to convince the US Army to purchase the Flyer because no convincing flight demonstration was performed. Thus, Wilbur went to Europe where aviation was in fever after the flight of Santos-Dumont. Orville remained in the United States to continue the pursuit of a contract to sell Armed Forces planes. They intended to improve their plane and secure European investors to open an assembly line. In France, Wilbur Wright set up shop in a field near Le Mans that the French automobile manufacturer Leon Bollée provided. Wilbur began working on the planes they had shipped to France at the end of 1907. They were in terrible shape - French Customs had repacked them poorly. It took him six weeks to assemble an airplane, even with the help of the mechanics that Bollée provided. When it was completed, it became Flyer A, incorporating a series of modifications, among them a new 30-hp engine. The new airplane weighed 544 kg, being characterized this way by a weight-to-power ratio of 17.7 kg/hp. The first flight was delayed because of bad weather. Finally, on August 8, 1908, the weather cleared. In front of a small crowd that included the aviators Louis Blériot, Ernest Archdeacon, Henry Farman, and Hubert Latham. At this time Wilbur made a brief but perfect flight that astounded his audience. He followed up with several more flights - each longer than the previous one. The flightworthiness of his airplane and his skill as a pilot were impressive. By October 15, he had taken up 30 passengers. These flights took place at a landing ground at Auvours. On December 8, 1908 Wilbur established a world record flying at a height of 115 m. In the same month he performed a flight covering impressive 124.7 km. In France an agreement was signed with the Société Ariel and in Britain with Short Brothers of Eastchurch. Both companies produced the passenger carrying machine Wilbur had demonstrated at Le Mans. The design was a biplane in every sense for it had double elevators, main plains and rudders. The rudders were placed further aft than in the brothers' 1905 design for better controllability. The pilot sat on the wing edge with the elevator control on his left. On his right was another stick which controlled both the rudders and wing-warping (independently). As with previous Wright designs, there were no wheels, and so take offs continued to be from a wooden rail, assisted by a weight and derrick mechanism. After landing, the machine had to be carried back to the rail on a wheeled trolley.

During the demonstration flights in Europe in 1909, the Wright brothers also met the wealthy businessman J.P. Morgan. Later that year, Morgan introduced the Wrights to a group of New York financiers who were interested in backing the fledgling aviation industry. These investors helped the Wright brothers establish the Wright Company, which was founded in November 1909. In January 1910, the Wright Company set up a factory in Dayton, Ohio. They also established a flying field and flight school at Huffman Prairie, site of the Wrights' flights after their history-making Kitty Hawk flight. Orville Wright and Charlie Taylor, their longtime mechanic, also set up a flying school in Montgomery, Alabama, in March 1910, where Maxwell Air Force Base would later be located. Orville immediately began the instruction of the first five men who became members of the Wright exhibition team.

Meanwhile in the U.S., on December 23, 1907, the U.S. War Department issued Specification No. 486 for a "Heavier-than-air Flying Machine." It stated that the aircraft must be able to carry two men for a distance of 125 miles (201 kilometers) at a minimum speed 64 km/h. It must be able to stay aloft for one hour between refueling, land without damage, be transportable on an Army wagon, easily steerable in all directions, and at all times be under perfect control and equilibrium. These were, in fact, the specifications that the Wrights had earlier told the War Department they could meet. On January 27, 1908, the Wrights submitted their formal bid to the War Department for one aircraft that would cost $25,000. This was considerably less than the $200,000 they had wanted to charge the French government the year before. Only one other bid would be considered - from Octave Chanute's old partner and their acquaintance, Augustus Herring. Back in Dayton, Orville was busily working on the plane for the Signal Corps with his two helpers - Charlie Taylor and Charlie Furnas. He was also writing letters and articles for Scientific American, Aeronautics, Century magazine, and other journals. On May 14, 1908, the mechanic Charlie Furnas became the Wrights' first airplane passenger in history. Orville and Furnas made several flights that day, but in a solo flight, Orville made an error with the elevator lever, and the plane dove into the ground at 64 km/h. He was unhurt, but the plane was wrecked. Some months later Orville demonstrated a Model A to the US Army at Fort Myer. From September 3, 1908 he made 10 flights, but on September 17 he crashed after the starboard propeller blade broke. His passenger, Lt Thomas Selfridge was fatally injured and Orville suffered a broken hip. Military trials were postponed until the following year, when a replacement aircraft would be available. The 1909 Signal Corps Flyer successfully completed the Army's acceptance trials and in July became the world's first military airplane accepted into military service.

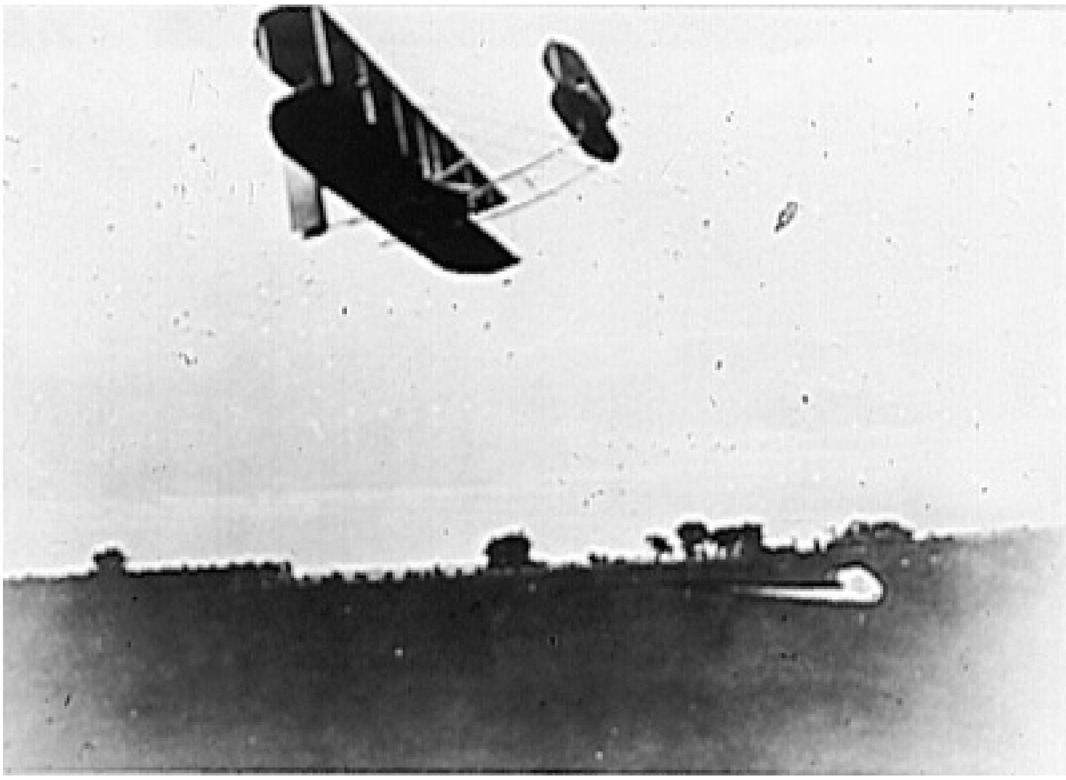

Fig. 13 – Photograph of an alleged 12-mile flight on September, 29 1905 with Flyer III.

2.5 The patent war

In 1908 the brothers warned Glenn Curtiss not to infringe their patent by profiting from flying or selling aircraft that used ailerons. Curtiss refused to pay license fees to the Wrights and sold a plane to the Aeronautic Society of New York in 1909. The Wrights filed a lawsuit, beginning a years-long legal conflict. They also sued foreign aviators who flew at U.S. exhibitions. The brothers' licensed European companies, which owned foreign patents the Wrights had received, sued manufacturers in their countries. The European lawsuits were only partly successful. Despite a pro-Wright ruling in France, legal maneuvering dragged on until the patent expired in 1917. A German court ruled the patent invalid due to prior disclosure in speeches by Wilbur Wright in 1901 and Octave Chanute in 1903. The

Wrights did make agreements with some U.S. groups that sponsored airshows and collected license fees from them. The Wrights won their initial case against Curtiss in February 1913, but the decision was appealed.

From 1910 until his death from typhoid fever in 1912, Wilbur took the leading role in the patent struggle, traveling incessantly to consult with lawyers and testify in what he felt was a moral cause, particularly against Curtiss, who was creating a large company to manufacture aircraft. The Wrights' preoccupation with the legal issue hindered their development of new aircraft designs, and by 1911 Wright aircraft were considered inferior to those made by other firms in Europe. Orville and Katharine Wright believed Curtiss was partly responsible for Wilbur's premature death, which occurred in the wake of his exhausting travels and the stress of the legal battle.

The lawsuits against Americans companies that were trying to manufacture airplanes caused a huge setback to the North-American aerospace industry. In the beginning of World War I the production of aircraft in Europe largely surpassed that in America. American pilots in the WWI battlefield were sitting in more advanced European fighters.

In January 1914 a U.S. Circuit Court of Appeals upheld the verdict in favor of the Wrights against Curtiss, whose company continued to avoid penalties through legal tactics and because Orville was planning to sell the Wright company and did not follow up the legal victory. In 1917, with World War I underway, the U.S. government stepped in to supervise a cross-licensing organization in which member companies paid a blanket fee for the use of aviation patents, including the original and subsequent Wright patents. The Wright-Martin company (successor to the Wright Company) and the Curtiss Company (which held a number of its own patents) each received a US$2 million payment. The "patent war" ended, although side issues lingered in the courts until the 1920s. In a twist of irony, the Wright Aeronautical company (another successor) and the Curtiss Airplane company merged in 1929 to form the Curtiss-Wright corporation, which remains in business today producing high-tech components for the aerospace industry.

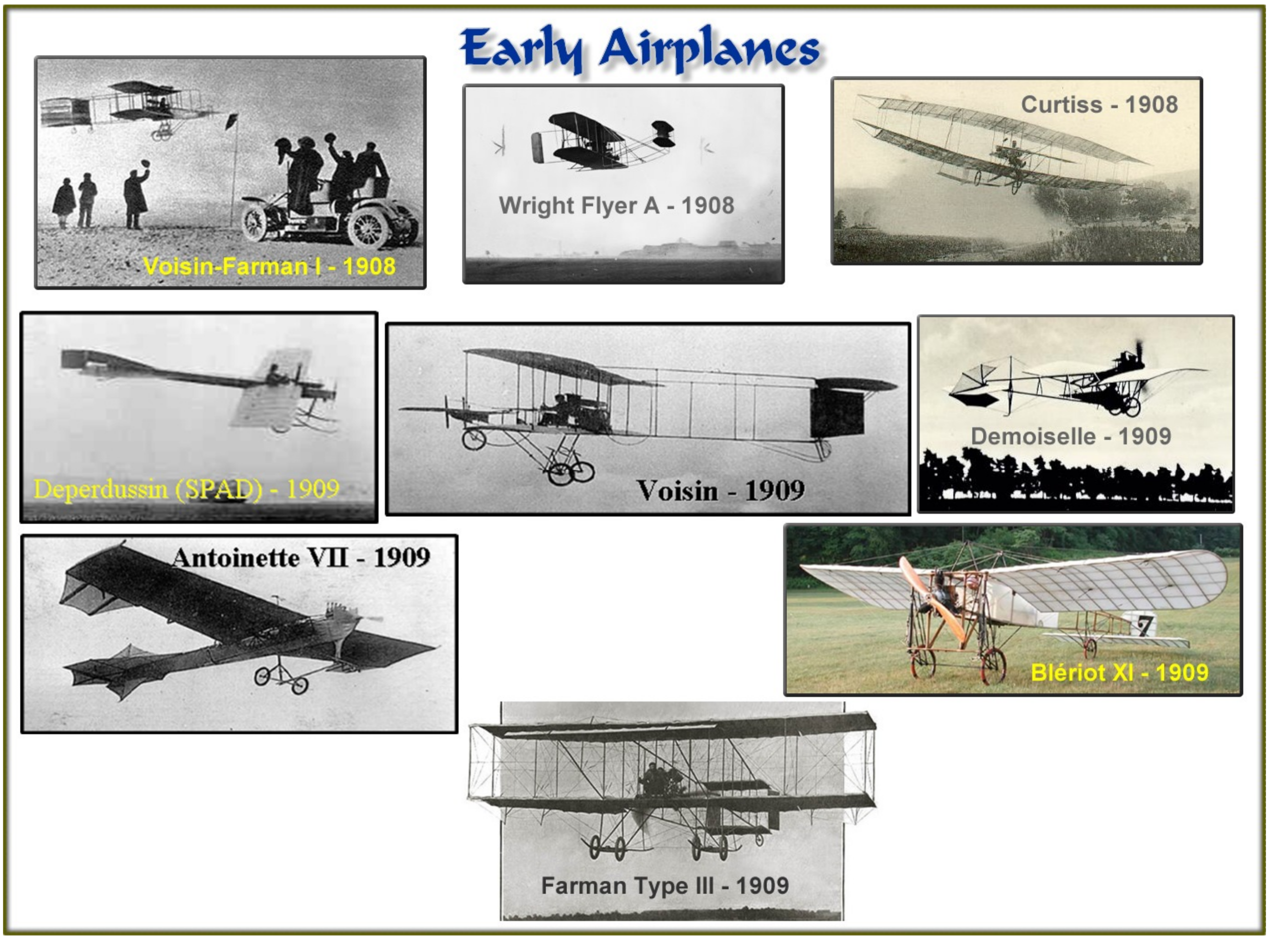

Fig. 14 – Some airplanes from the period 1908-1909.

The lawsuits damaged the public image of the Wright brothers, who were generally regarded as heroes. Critics said the brothers were greedy and unfair. Supporters said the brothers were protecting their interests and were justified in expecting fair compensation for secrets of their invention. Their long friendship with Octave Chanute collapsed after he publicly criticized their actions.

2.6 Dumont set standards

Meanwhile, Santos-Dumont's was working in a revolutionary airplane, back to the monoplane configuration as he had dreamed before the flights with 14*Bis*. The single-engined Demoiselle aircraft (**Fig. 14**) was Dumont's final design. Dumont performed a large number of experimentation with Demoiselle, which received successive designations – No. 19 to 22. The Demoiselle was a groundbreaking experience in terms of construction and configuration. It was produced in different countries, including Germany, France, Holland, and the United States. This aircraft was employed as Dumont's personal transportation and he willingly let others make use of his design. The fuselage consisted of a specially reinforced bamboo boom, and the pilot sat beneath between the main wheels of a tricycle landing gear. The Demoiselle was controlled in flight partially by a tail unit that functioned as both elevator and rudder and by wing warping (No. 20).

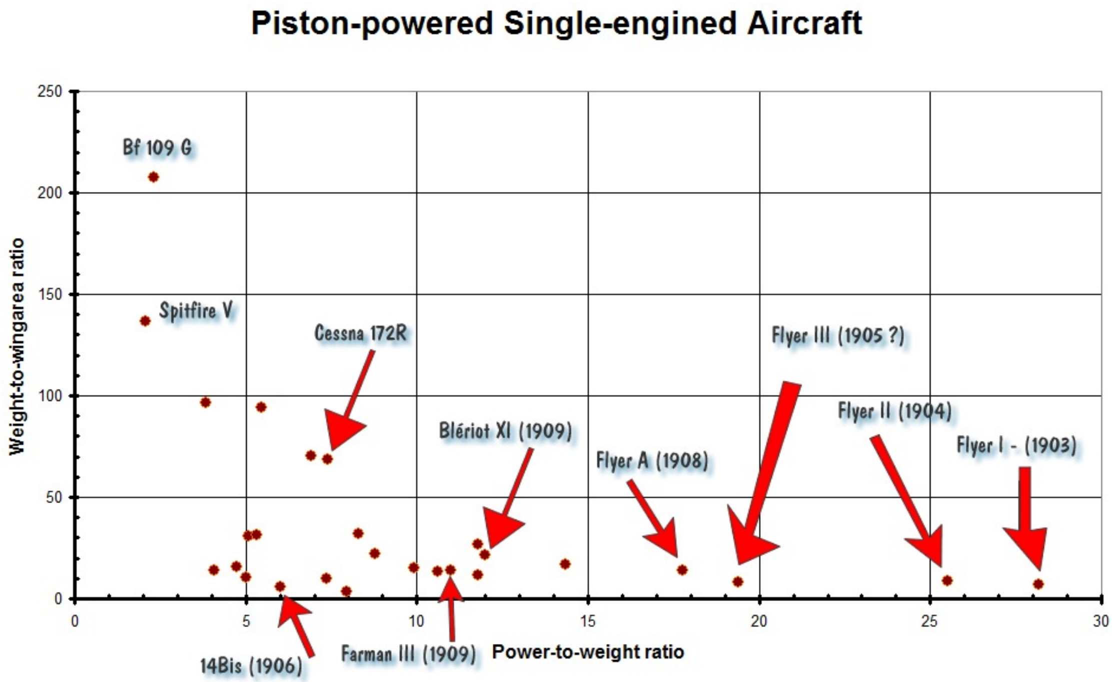

Fig. 15 – The Wright brother continuously improved the weight-to-power ratio of their machines. However, the graph shows that the Flyer figures are higher than any single-engine piston-powered aircraft of all time. This explains the need for a catapult-launching system or suitable wind conditions to takeoff for the later versions; the first two versions can be considered a powered glider.

The Demoiselle airplane had a wingspan of 5.10 m and an overall length of 8 m. Its weight was little more than 110 kg with Santos Dumont at the controls. The pilot was seated below the fuselage-wing junction, just behind the wheels, and commanded the tail surfaces using a steering wheel. The cables of sustentation of the wing were made of piano ropes. Initially, Santos-Dumont employed a liquid-cooled Dutheil & Chalmers engine with 20 hp. Later, the great inventor repositioned the engine to a lower location, placing it in front of the pilot. Santos-Dumont also replaced the former 20-hp engine by a 24-hp Antoniette and carried out some wing reinforcements. This version received the designation No. 20. Due to structural problems and continuing lack of power, Santos-Dumont introduced additional modifications into the Demoiselle's design: a triangular and shortened fuselage made of bamboo; the engine was moved back to its original position, in front of the wing; and increased wingspan. Thus, the No. 21 was born. The design of no. 22 was basically similar to No. 21. Santos-Dumont tested opposed-cylinder (he patented a solution for cooling this kind of engine) and cooled-water engines, with power settings ranging from 20 to 40 hp, in the two variants. An interesting feature of the water-cooled variant was the liquid-coolant pipeline which followed the wing lower side lofting to improve the aircraft aerodynamics.

The plane could be constructed in only fifteen days. Possessing outstanding performance, easily covering 200 m of ground during the initial flights and flying at speeds of more than 100 km/h, the Demoiselle was the last aircraft built by Santos-Dumont. He used to perform flights with the airplane in Paris and some small trips to nearby places. Flights were continued at various times through 1909, including the first cross-country flight with steps of about 8 km, from St. Cyr to Buc on September 13, returning the following day, and another on the 17th, of 18 km in 16 min. The Demoiselle that was fitted with two-cylinder engine became rather popular. The French WWI- ace Roland Garros flew it at the Belmont Park, New York, in 1910. The June 1910 edition of the Popular Mechanics magazine published drawings of the Demoiselle and affirmed that the Dumont's plane was better than any other that had been built to that date, for those who wish to reach results with the least possible expense and with a minimum of experimenting.

American companies sold drawings and parts of Demoiselle for several years thereafter. Santos- Dumont was so enthusiastic about aviation that he released the drawings of Demoiselle for free, thinking that aviation would be the mainstream of a new prosperous era for mankind. Clément Bayard, an automotive maker, constructed several units of Demoiselles, which was sold for 50,000 Francs. The design of Demoiselle clearly influenced that of the Blériot XI airplane, which was used for the British Channel crossing in 1909.

Louis Blériot, a friend of Santos-Dumont, succeeded in crossing the English Channel for the first time in 1909. The First World War greatly stepped up aviation growth. In 1911, Blériot's company released the first transport aircraft with enclosed cabin, which was christened *Aèrobus*. In November 1909 Igo Etrich made the first flight in Austria in an Austrian-designed and -built airplane, at Wiener-Neustadt[2]. It was called the *Taube* (pigeon) and was a monoplane with bird-like wings. Subsequently it was produced in refined form as a single, two- and three-seater. The maiden flight of Luftlimousine took place on May 7, 1912, only six days later than the Avro Type F (**Fig. 16**), the later considered the first aircraft with a fully enclosed cabin to fly[2]. The top speed of the Etrich aircraft with three passengers on board was 106 km/h. Shortly after the World War I, the first airlines were founded and started operating with retrofitted bomber planes. German manufacturer, Junkers, designed and produced the world's first all-metal planes, as some were used in combat in the later stages of the First World War. The Junkers F.13 was the first airplane intended for passenger transportation, having made its maiden flight in 1919.

The Demoiselle took part in some airshows in the United States (**Fig. 17**) in early 1910s. Most of the planes displayed in those events were from French origin. They contributed to the development of the North-American aviation. When William Boeing witnessed an air show in 1910, where Farman airplanes played the main role, aviation became an instant obsession. The show was a catalyst that would lead him to build his own plane and start his own airplane company, Pacific Aero Products, in 1916. This company evolved into the worldwide known Boeing Co.

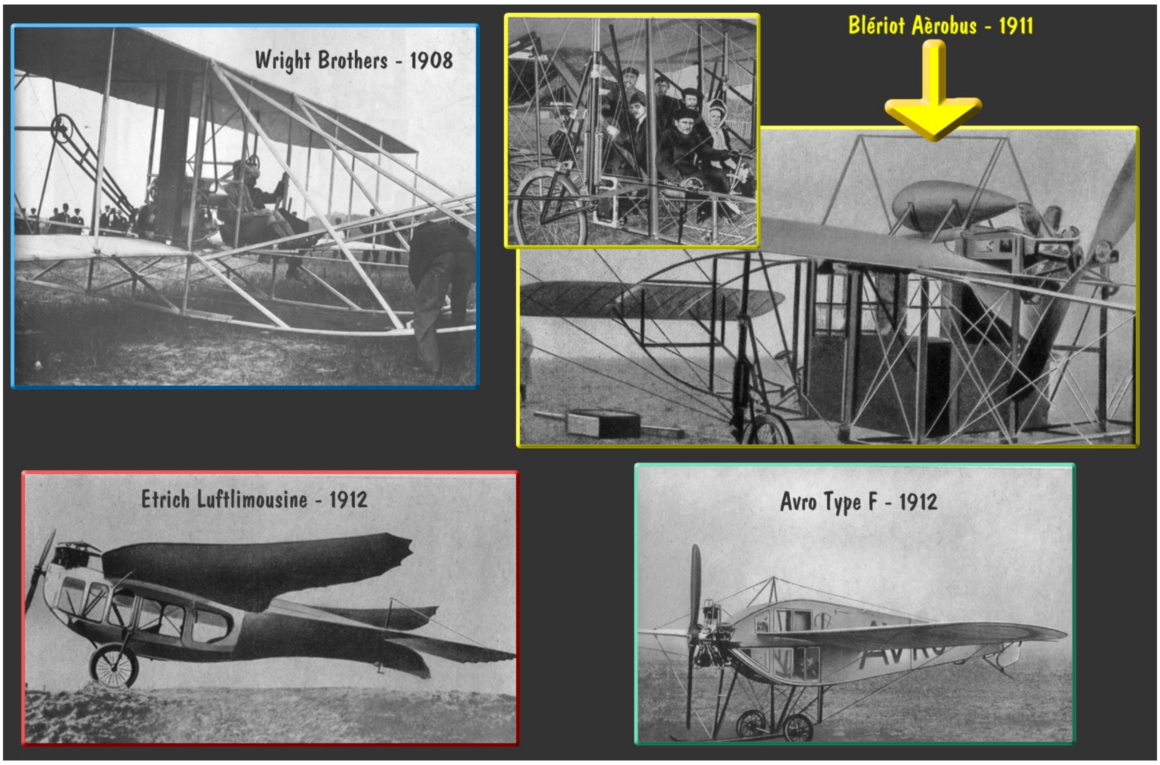

Fig. 16 – First passenger airplanes.

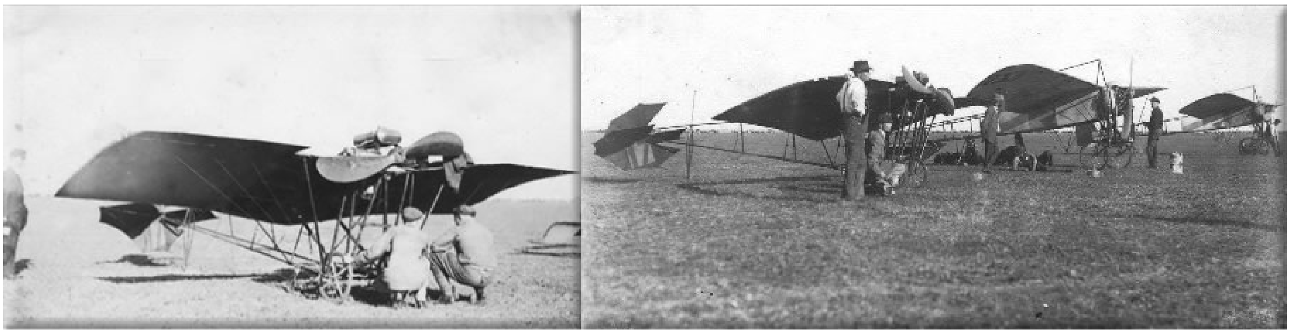

Fig. 17 – Demoiselle and Blériots airplanes taking part in an Airshow in Texas, January 1910.

2.7 Back to airships

Along World War I, nearly 100 Zeppelin airships were built. Millions of rivets and thousand kilometers of wiring were necessary to build a single airship. However, the most unusual commodity employed in the construction of Zeppelin airships was the bowel-beaten skin. Before that material was sewed to compose the gas bags, it had to be carefully cleaned. The amounts of bowel-beaten skin reached astonishing figures: 50 thousand per bag, over 700 thousand per airship.

At the end of the war, the German Zeppelins that had not been captured were surrendered to the Allies by the terms of the Treaty of Versailles, and it looked like the Zeppelin Company would soon disappear. However, Dr. Hugo Eckener, who had assumed the company's helm upon Count Zeppelin's death in 1917, offered the U.S. government a huge Zeppelin as war reparation for the U.S. Military to use. Although the Americans feared the German Zeppelins, they accepted Eckener's offer. Remembering the bombardment of London in World War I, it was feared that German airships could bomb New York. Propaganda movies were exhibited showing Zeppelins carrying self-defense fighters on a bombing raid to that coastal American city. The paranoia was so outspread that a Congress Act was later issued prohibiting American companies to deliver Helium gas to Germany. Paradoxically, the ordering of the ZR3 (also designated the LZ-126) allowed the Zeppelin Company to stay in business. On October 13, 1924 the U.S. Navy received the German ZR3. Since no Insurance Company accepted to cover the transaction, the airship was delivered personally by Eckener, who was said to have the ability to sense storms even at a considerable distance; ability he had acquired during the time he had spent sailing on Lake of Constance. When the various restrictions imposed by the Treaty of Versailles on Germany were lifted, Germany was again allowed to construct airships. It built three giant rigid airships: the LZ 127 Graf Zeppelin, LZ 129 Hindenburg, and LZ 130 Graf Zeppelin II. The Graf Zeppelin is considered the finest airship ever built. It flew more miles than any airship had done to that time or would in the future. Its first flight was on September 18, 1928. In August 1929 it circled the globe. Its flight began with a trip from Friedrichshaften, Germany, to Lakehurst, New Jersey, allowing William Randolph Hearst, who had financed the trip in exchange for exclusive rights to the story, to claim that the voyage began from American soil. Piloted by Eckener, the craft stopped only at Tokyo, Japan, Los Angeles, California, and Lakehurst. The trip took 12 days - less time than the ocean trip from Tokyo to San Francisco. During the 10 years the Graf Zeppelin flew, it made 590 flights including 144 ocean crossings. It flew more than one million miles (1,609,344 kilometers), visited the United States, the Arctic, the Middle East, and South America (**Fig. 18**), and carried 13,110 passengers.

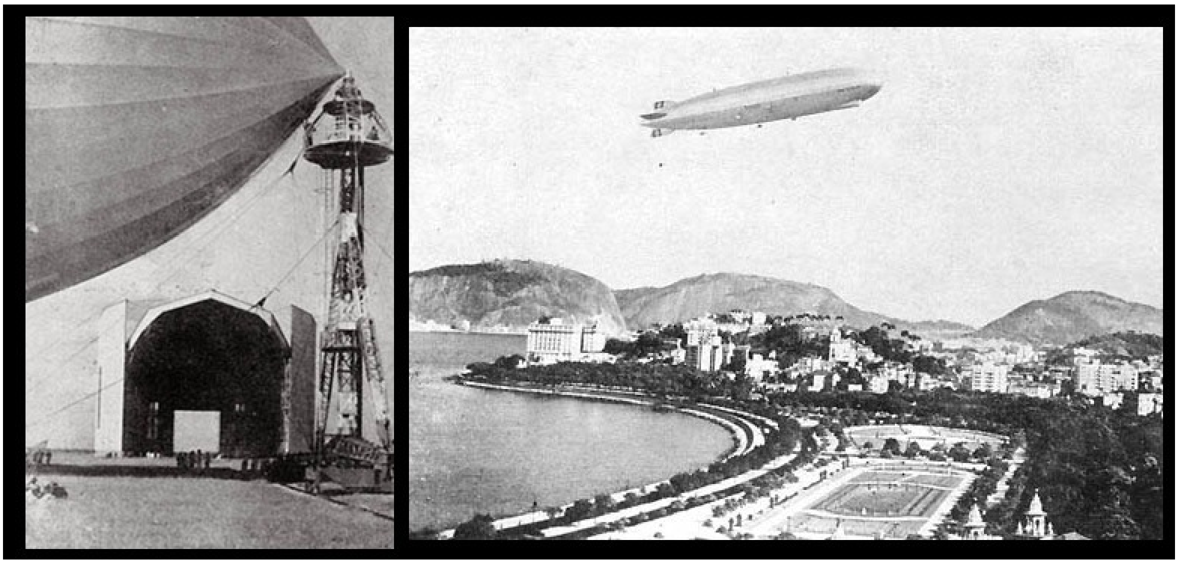

Fig. 18 – LZ 127 Graf Zeppelin in Rio de Janeiro in the 30s.

3. Flying is ingrained in Brazil's soul

Besides Santos-Dumont, Brazil was populated by many flight enthusiasts in the XIV century. The Republic of Brazil was proclaimed on November 15, 1889. During the 1893 Armada Rebellion, the rebels took over most of the fleet and took control of the Guanabara Bay in Rio de Janeiro. They used the captured ships to bomb the city of Rio de Janeiro, at that time capital of Brazil, and demanded President Floriano Peixoto's resignation. Without a fleet to attack the rebel's ships, the President went along with Congressman Augusto Severo's suggestion of building an airship "with an eye on the possibility of using the aircraft in the fight against the rebels". The Brazilian Armed Forces were not altogether unfamiliar with the use of balloons in military operations. During the Paraguay War, Brazil used captive balloons to watch enemy movements. Augusto Severo went to Paris in 1893 to commission and supervised the construction of an airship, called Bartholomeu de Gusmão, by the renowned establishment of Lachambre & Machuron (**Fig. 19**). In February 1894, the airship took to the air, but during stability tests it had an accident. As the sailors' rebellion had come to an end, the government lost interest in Severo's ideas; his airship went unrepaired and was ultimately scrapped. From then on, he had to use his own private resources to proceed with his work. Severo died in Paris soon after his recently built airship Pax took off in 1902. Other Brazilian pioneers designed and built airships. Júlio Cesar Ribeiro de Souza, from the state of Pará, was the first to attempt to design and build an airship in Brazil. He piloted his airships Vitória in 1881 and Cruzeiro in 1886, both in Paris.

Fig. 19– Bartholomeu de Gusmão airship in Rio de Janeiro, 1894.

The Navy was the first to establish a military aviation school and later on, the air corps was created. As early as 1908, the Rio de Janeiro press published articles advocating the idea that the Navy should have airships for ocean and river reconnaissance. On January 7, 1910, the São Paulo, the first single-engine aircraft wholly manufactured in Brazil, made its maiden flight in São Paulo. Demetre Sensaud de Lavaud, a Frenchman who settled in Brazil, built the plane. J. D'Alvear built the second airplane produced in Brazil. It was a single-engine monoplane and made its maiden flight in 1914. Although his plane was a success, D´Alvear gave up his aircraft manufacturing efforts after this. Army lieutenant Marcos Evangelista Villela Júnior was sent to France in order to supervise the assembly of some Blériot aircraft that Brazil had purchased from that country. In 1918, Villela Júnior realized the potential of the airplane as a military weapon and went on to design a surveillance single-engine plane, which he called Aribu. Owing to its excellent flight performance, the Brazilian Army purchased the aircraft. With the Army's assistance, Villela built another aircraft, which he called Alagoas, and this time it was intended for instruction. On November 11, 1918, the same day in which the end of the First World War was signed, the Alagoas made its maiden flight and the first members of the Military French Mission were hired by the Brazilian Army to organize its School of Aviation arrived in Brazil. Captain Etienne Lafay, who later helped produce two aircraft in Brazil, was among this group. Lafay and engineer, Braconnot worked in the shops of industrialist, Henrique Lage, from the ship repair and shipping industries, and designed a single-engine biplane similar to the French Caudron G.3. Completed in April 1920, the aircraft was christened Rio de Janeiro. Next development was the 5-seater Independência biplane with its tractor- pusher configuration powered by two Charget rotary engines, which were outdated at the time. In the following decade, several attempts to build and manufacture aircraft in Brazil failed. Most of the aircraft barely left the drawing board or prototype phase. Delivery of the first Muniz M-7 biplanes in 1936 marks the start of the first aircraft serial production in Brazil. The M-7 was manufactured by Henrique Lage's Companhia Nacional de Navegação Aérea, which unsuccessfully tried to produce Blackburn and Bristol airplanes under license in Brazil, purchasing some of the necessary tooling. The time taken to start an aircraft serial production in Brazil and D'Alvear's experience indicate that the country lacked an industrial policy in the first quarter of the 20th century. But the positive results that were obtained were due to the private initiatives. The first aircraft serial production in Brazil was made possible by the good relationship between the Army and the civil industry with the support of President Getúlio Vargas. In the future, government support, particularly from the military, would be essential for the creation of EMBRAER.

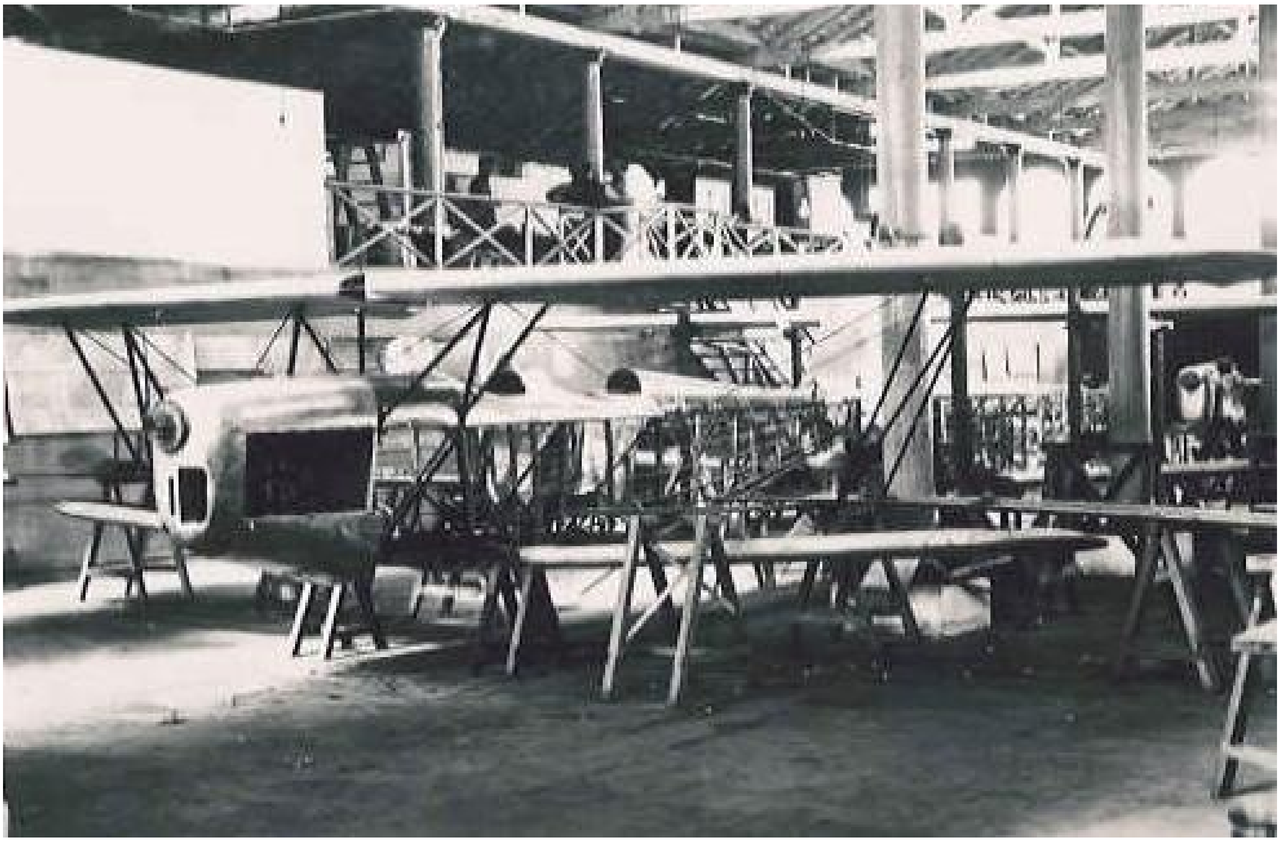

Fig. 20 - The graceful Muniz M-7 biplane was the first aircraft serially manufactured in Brazil.

In 1927, the same year in which the Army created its aircorp, captain Guedez Muniz started attending a course at the Superior School of Aeronautics in France, where he designed his first three aircraft - M-1, M-3, and M-5. In the following year, Muniz supervised the manufacturing and testing of the aircraft that France was producing for Brazil. Due to this fact, Muniz was able to become more familiar with three French aeronautical companies: Caudron, Farman, and Potez. Later on, the M-5 was manufactured by Caudron for the Brazilian Army. Back in Brazil in 1931, he remarked, "the happiness of those people was based on industrialization. They were not simply countries that produced or consumed agricultural stuff and other raw materials." Therefore, Muniz believed it was necessary for Brazil to establish an aeronautical industry, not merely because of military considerations, but also as a driving force to modernize the country. Aircraft manufacturing would also have a positive influence on aircraft component factories. In Brazil, Muniz designed the M-7 biplane trainer, the first aircraft serially produced in Brazil (**Fig. 20**). In 1935, two M-7 prototypes were built at Campo dos Afonsos, an Air Force base in Rio de Janeiro. This enabled Muniz to reconsider his ideas about serial production of aircraft in Brazil. The Santa Luzia Mill produced the rear landing gear and the main wheels from cast light metal alloys; the CNNA - Companhia Nacional de Navegação Aérea, which produced welded steel rudders, and the wing skin of fabric, which was produced by a domestic textile factory. Several other items were used on the prototypes and serial models were manufactured in Brazil.

Muniz advocated the use of Brazilian woods to build airplanes and also promoted the implementation of special steels and aluminum plants. He believed that the first step towards the manufacture of engines should be the signing of a production license agreement with a major foreign manufacturer. Muniz wanted the federal government to subsidize the research on Brazilian woods conducted by the IPT - Instituto de Pesquisas Tecnológicas - located in the state of São Paulo. He proposed the creation of an Air Ministry to coordinate all aviation-related activities. He also wanted the government to purchase small airplanes to be donated to air clubs. The manufacture of general aviation airplanes would become a valuable research laboratory and would provide skilled people to the aerospace sector during its beginning. Ary Torres, IPT director, endorsed Muniz's ideas and suggested the creation of an aeronautical engineering course in Rio de Janeiro, as well as the formation of a commission consisting of "technicians from the ministries of War, Navy, and Aviation, and specialized civil engineers, with funds and authority to start the manufacture of aircraft in the country." In 1936, CNNA manufactured and delivered the first two out of 26 Muniz M-7 aircraft. Thus, the Brazilian aeronautical industry was born, based on Muniz's efforts and ideas and the support of President Getúlio Vargas. In 1939, the Army Ministry created an aeronautical engineering specialization course at Escola Técnica do Exército in Rio de Janeiro, the first undergraduate course in aeronautical engineering in Brazil.

4. Aeronautical industry before the creation of the Centro Técnico de Aeronáutica (CTA)

This phase of the Brazilian aeronautical industry, covering the 1939-1946 period, was marked by the involvement of private companies, which depended entirely on government support and purchasing power, and state-controlled production of aircraft. Most aircraft production ventures were carried out often in a disorderly fashion. The manufacture of military aircraft was geared to specific interests and did not fit into a centralized policy. Private aircraft production was oriented towards fulfilling air club needs and most products were obsolete. Unable to reach large-scale production, most initiatives became a commercial disaster. Fortunately, the driving force behind the country's aeronautical development in conjunction with the training of specialized labor, ultimately led to the creation of the CTA - Centro Técnico de Aeronáutica. From the very beginning, CTA's activities focused on aeronautical research, teaching and development, as well as aircraft certification. IPT's renowned Wood Laboratory evolved into an aeronautical department responsible for manufacturing different experimental aircraft and sailplanes. Besides contributing to create specialized labor, IPT designed planes for private companies, such as the single-engine Planalto airplane (CAP-3) and the successful high-wing monoplane CAP-4 Paulistinha marketed by the Companhia Aérea Paulista (CAP). The Paulistinha, in turn, was derived from the EAY- 201, originally intended to be produced by EAY – Empresa Aeronáutica Ypiranga, which had been previously manufactured on only sailplanes. The EAY-201 was a high-wing, single-engine biplace airplane, made out of wood with a steel fuselage structure covered by fabric and the wings being made of plywood with a fabric skin. In 1941, EAY sold the EAY-201 prototype, but bought it back and made sweeping design changes. Then, IPT was commissioned to develop the design of an aircraft based on the EAY-201. Thus, through the hands of Romeu Corsini and Adonis Maitino, the Paulistinha was born. CAP, owned by industrialist, Francisco Baby Pignatari, followed by Sociedade Aeronáutica Neiva after CAP went bankrupt, produced 1,019 Paulistinha aircraft. In 1935, both the EAY-201 prototype and the Muniz M-7 made their maiden flights and later on, the Muniz M-9, a M-7 derivative, was left on the drawing board. The Muniz M-9 prototype was completed in 1937 and certified in February of 1938. In May 1939, the Army first ordered 20 M-9s. Five M-9 aircraft were exported and an order for another 20 was placed by the military and manufactured by CNNA up until 1943. Guedes Muniz went on to design the M-10 and the M-11, the latter one being a low-wing monoplane entirely made from native woods. Both programs were discontinued. The M-11 was cancelled because Brazil took delivery of a large number of PT-19s through the Loan and Lease program of the United States Government. This led to the manufacture under license of this aircraft by the Fábrica do Galeão. CNNA continued producing other types of aircraft until 1948, when it was closed down. In August 1947, a modified Muniz M-9 was the first agricultural aircraft in Brazil.

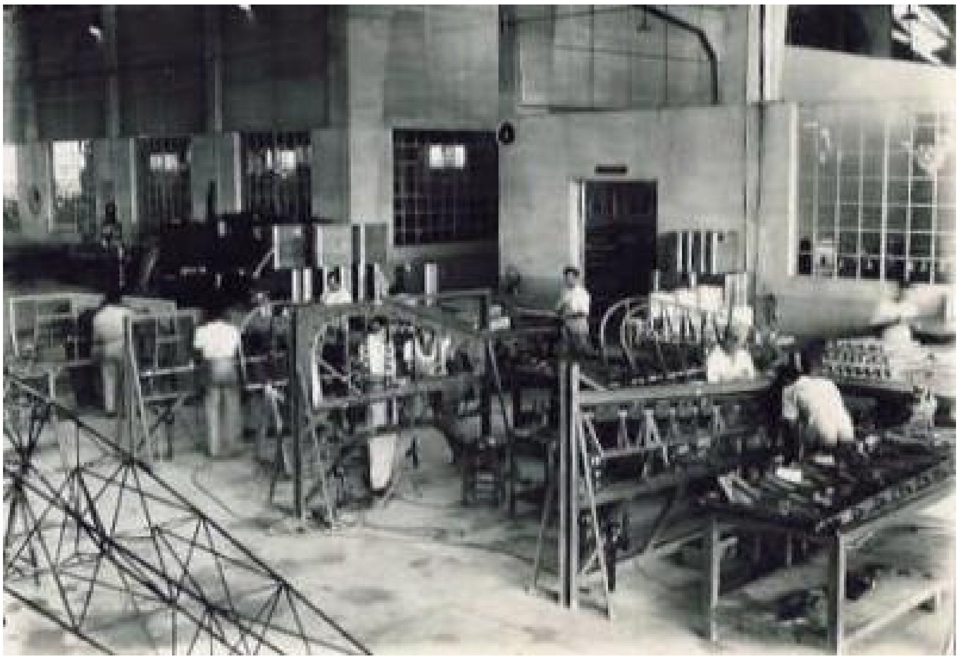

Fig. 21 – manufacturing of 3FG aircraft components at Fábrica do Galeão.

In 1936, the Brazilian Navy signed an agreement with the Focke-Wulf Flugzeugbau AG in order to assemble in Brazil under license four of its aircraft types. Indeed, only two out of the four types were actually assembled in the country. In 1937, the Fábrica do Galeão, a navy-manufacturing complex was then raised to the manufacture of the German aircraft, which assembled 20 units of the Fw 44 Stiegelitz. In the following year, 20 additional Pintassilgos (name of a native bird), as the Brazilian Fw 44 were also known, were manufactured. The twin-engined Fw 58 Weihe, which received the Brazilian type 2FG, became more famous than the Stieglitz in Brazil. After the first prototype of the Brazilian Weihe was constructed, which helped in the training of pilots and mechanics on the type, two series of the aircraft left the assembly line of Fábrica do Galeão. The first series was assembled with German components, only; the second batch was produced with increasingly locally manufactured parts. The Weihe was mainly employed in patrol and bomber roles during the World War II. After the war broke out, the diplomatic relations between Germany and Brazil ceased and the Galeão's plant started to assemble American airplanes, instead.

After the Fw 48, the Fairchild PT-19 - 3FG under Brazilian designation - (**Fig. 21**) was the next aircraft built under license with over 400 units produced. However, the PT 19 was an old-fashioned aircraft model, built with wood instead of employing metallic construction like most airplanes at that time. In 1950, the Fábrica do Galeão hired the Austrian engineer Paul Baurmgart. He led the construction of an experimental helicopter, actually, an adaptation of an old European design. The prototype performed four flights and received the designation 4FG. The type never saw serial manufacturing and was destroyed later in an accident. In 1952, the Ministry of Aeronautics determined for the Galeão's plant the manufacture of a light airplane for the training of civil pilots. Marc William Niess had designed the chosen model in 1949. His l-80 was already certified and had good handling characteristics. Marc Niess had undergraduated in engineering at the Polytechnical School and began to work at the Companhia Aeronaútica Paulista (CAP) in 1941. There, he took part in the designs of the Paulistinha and the Planalto light airplanes. In 1942, he moved to Companhia de Navegação Aérea, in Rio de Janeiro, where he worked until 1945, when he came back to CAP, remaining there until the company ceased its activities in 1948. 1-80 was a high-wing monoplane with structure of welded steel, wooden wing covered with fabric, and driven by one 80-hp engine. Two people could be transported in side-by-side arrangement. The model gained the denomination of 5FG at Fábrica do Galeão, indicating that it would be the fifth aircraft produced in series by the manufacturing plant. However, the Ministry of the Aeronautics fixed a tight deadline for the delivery of the airplanes: six months. The design was then modified with the substitution of the wing's fabric covering with plywood, which was on stock, and added two fuel tanks to increase the aircraft's endurance. The modifications, which increased 120 kg to the basic operating weight, downgraded the aircraft's performance and handling characteristics. In January of 1953, after 68 of the initial order of 80 units were manufactured, the production ceased. The last attempt for operating the Fábrica do Galeão plant occurred in 1953, when its installations had been leasehold to the Fokker Aeronautical Industries, a company formed by the Dutch Fokker and a group of Brazilian entrepreneurs. According to the agreement of shareholders, the Dutch company would integrate 50% of the total capital of company, of which 25% were in species and the remainder in technology. The Ministerial of Aeronautics placed an order for 100 and 50 units of the S11 and S12 models, respectively. The landing gear arrangement was the only difference between both models: the S11 had a bicycle configuration and the S12 a nose gear. The aircraft was a low-wing single-engined monoplane and were better known by their military designation T-21 and T-22. The Brazilian Air Force set a deadline of 5 years for the delivery of the airplanes. However, the contract caused a lot of strain in the Air Force. Some high officials were against a state company being overtaken by a private venture linked to a foreign investor. Only 35 units out of the initial order of 100 for the T-21 trainer were manufactured. The Brazilian Fokker went bankrupt in late 50s. Between 1960 and 1962, 15 additional S12 models were manufactured at Fábrica do Galeão, which by this time was back under control of the Ministerial of Aeronautics. In 1965, after this last batch was produced, the Fábrica do Galeão changed itself into a maintenance workshop of the Brazilian Air Force.

Fig. 22 – North American T-6 assembling line at Lagoa Santa plant.

The war surplus of American aeronautical industry provoked serious and harmful consequences for the Brazilian aeronautical industry in the post war period. In November of 1948, the Companhia de Navegação Aérea came to a standstill. In December of the same year, the São Paulo Aeronautical Company followed it. The Fábrica do Galeão had its activities practically paralyzed. The Lagoa Santa assembly plant changed itself into a workshop for aircraft overhaul of the Air Force. The Fábrica Nacional de Motores (National Engine Factory) was privatized being overtaken by foreign investors and started to manufacture cars and trucks instead of airplanes.

The Fábrica de Lagoa Santa (Lagoa Santa Manufacturing plant) was yet another attempt for manufacturing aircraft in Brazil. The factory was established early on in Getulio Vargas's administration. As early as 1935, a commission appointed by the Ministry of Roadways and Public Works composed of Army, Navy, and Civil Aviation representatives searched for a suitable location for a military aircraft factory. After conducting several studies and consulting a number of businessmen, a factory was opened in the city of Lagoa Santa, state of Minas Gerais, to assemble North American T-6 aircraft. Aircraft production started in 1946, ten years after the initially planned starting date. By that time, the T-6 aircraft had become obsolete. The production of the last remaining T-6s, out of an order for 81 aircraft, should increasingly use domestic content. Production came to a halt due to the difficulty in finding and training specialized labor in that part of the country and other problems related to the poor local infrastructure.

Sociedade Aeronáutica Neiva was founded by José Carlos de Barros Neiva to manually manufacture sailplanes. However, the Ministry of Aeronautics continued to import aircraft to be used by air clubs and Neiva intended to capture a slice of this market segment with domestically designed aircraft. By manufacturing the Paulistinha, the company managed to survive and grow during the difficult late 50's and early 60's period, when many other initiatives failed. Nevertheless, the Brazilian aeronautical industry was still entirely dependent on the government: 232 out of 242 Paulistinhas were ordered by the Ministry of Aeronautics. In 1959 Neiva unveiled the Regente, a metallic single-engined aircraft, to the MAer and, at the same time, developed the Campeiro, a new version of the Paulistinha fitted with a more powerful engine, increased visibility and radio. The MAer ordered 120 Regentes. The Regente was certified in 1963, but only a single prototype of the Campeiro was built. In addition, 40 units of the Regente Elo, a model with better rear visibility, were manufactured.

5. The Creation of Centro Técnico de Aeronáutica (CTA)

Established on January 20, 1941, through a decree-law, the Brazilian Air Force (FAB) originated from the combination of the Navy Aviation Corps and the Army Aeronautical Division. In the period from the end of World War II until the foundation of EMBRAER, the MAer played a major rolein developing the Brazilian aeronautical industry under the management of FAB's top-ranking officers. This period was also marked by the design and production of metallic instruction airplanes and by the continuing manufacture of the Paulistinha by Neiva. A team led by then Major Ozires Silva at the Instituto de Pesquisa e Desenvolvimento (IPD/PAR), a CTA unit, designed the twin-engined Bandeirante.

Lieutenant-Colonel Casemiro Montenegro Filho struggled to create CTA. Montenegro Filho was one of the first aeronautical engineers to undergraduate from the Escola Técnica do Exército in 1942. After some trips to the United States, he started to promote the opening of an aeronautical research center in Brazil. Montenegro contacted Prof. Richard Smith from the Massachusetts Institute of Technology and asked him to help to implement the new technological center. Professor Smith came to Brazil some time later. In January of 1946, during acting-president José Linhares's administration, a Committee for the Organization of the Aeronautics Technical Center (COCTA) was formed. This is considered the origin of the CTA. In 1953, a law was enacted to dissolve the committee and create the CTA in São José dos Campos, state of São Paulo. At first, the CTA consisted of two units: the Instituto Tecnológico de Aeronáutica (ITA) and the IPD. Initially, the IPD engaged most engineers who graduated at ITA.

ITA invited German designer Professor Henrich Focke to come to Brazil. Focke was one of the founders of the Focke-Wulf factories and the Focke-Achgelis helicopter manufacturer. Focke had invented the helicopter collective mechanism and developed helicopters Fa 61 and Fa 223. The Fa 61 is considered the first successful helicopter in history, and the Fa 223 was the first helicopter to be serially produced. In Brazil, Focke was keen to develop the Convertiplane, a single-engined aircraft capable of taking off vertically and fly like a regular plane based on a set of four tilting large propellers. This project involved 40 people, including Joseph Kovacs who had worked at IPT in the design and building of many aircraft. The Convertiplane program failed to achieve practical results as "only two bench tests were carried out with a engine not operating at full power", according to Kovacs. In 1953, the Convertiplane project was discontinued.

Three of the four first aircraft manufactured by Embraer were designed at IPD: Bandeirante, the agricultural airplane Ipanema, and the Urupema glider. The founding of Embraer resulted from the efforts of a group of engineers who worked at the IPD under Ozires Silva's leadership. Thus, the origin of Embraer is closely associated to the CTA. Hans Swoboda, a member of the Convertiplane project who had settled in Brazil, helped to design the Beija-Flor helicopter at the IPD in 1955.

Conveniently located in São José dos Campos, the CTA attracted other aeronautical companies to the city even before the creation of EMBRAER. One such company was Sociedade Aerotec, founded in 1962, which started off by developing the Uirapuru, a metallic single-engined aircraft whose maiden flight was performed in 1965. In 1967, the company was contracted to build 30 Uirapurus in order to replace aging T-21 and T-22 planes. Then, Aerotec received an order for 40 aircraft and also exported to Bolivia and Paraguay. In March of 1981, the Tangará, which replaced the Uirapuru, performed its maiden flight. While the MAer supported the Tangará design and construction of the prototype, it did not order any airplane. From then on, Aerotec restricted itself to producing parts of the Ipanema and Piper aircraft manufactured by EMBRAER and Neiva, and ultimately closed down in 1987. In the early 60's, Neiva embarked on a project to develop the T-25 Universal instruction plane to substitute the North American T-6. In 1966, the Universal prototype took its first flight. It was a metallic airplane featuring retractable landing gear and capable of transporting weapons. The Ministry of Aeronautics placed an order for 150 units of T-25. After the Universal, Neiva unsuccessfully tried to market Lanceiro, a civil version of Regente. Unable to obtain aircraft orders, Neiva faced a financial crisis and was later on purchased by EMBRAER. The Brazilian aeronautical industry has met many difficulties since the São Paulo monoplane that was built in 1910. We should point out; however, the pioneering endeavors of the military to provide the country with a modern aeronautical industry. In order to serially produce the Bandeirante airplane, the government decided to create a new company. For this reason, EMBRAER was created on August 19, 1969. Three main factors accounted for the failure of the previous attempts to create a Brazilian aeronautical industry before EMBRAER was founded: lack of continuous governmental support; lack of technologically advanced products to compete in international markets, and lack of special credit lines. EMBRAER was able to successfully overcome all this barriers.

6. The twin-turboprop Bandeirante

Brazilians had always dreamed of building multi-engined aircraft however, more often than not, new designs hardly left the drawing board. On May 25, 1922, the Independência twin-engined biplane (**Fig. 23**) performed its first flight. It had a pushpull twin-engine built by Capitan Etienne Lafay, equipped with rotary engines, which were obsolete at that time. Later on, Independência made several long-endurance flights, but never saw serial production. A little before the start of World War II, the Galeão Factory assembled two dozens Focke Wulf 58 Weihe twin-engine planes under license. After the fabrication of Weihe, there was a plan to start the serial production of the four- engined Focke-Wulf 200C Condor transport airplane. The elegant Fw 200C was so advanced that it made a direct flight from Berlin to New York in 1938, one year after the Hindenburg tragic accident, an event that heralded the end of transatlantic passenger transportation by airships. In Brazil, the airplane was operated by Condor Syndikat, which was later nationalized under the name Cruzeiro. This fact, together with the plans to expand Galeão Factory, led to the idea of producing the aircraft in Brazil and, to this end, Focke-Wulf Flugzeugbau AG was approached. Some production tooling was shipped to Brazil. However, these plans were abandoned with the start of World War II, and the Fw 200C was never produced in the country. Galeão Factory continued manufacturing different types of single-engined aircraft by 1962, but instead of assembling kits for the twin-engined Gloster Meteor, the first English jet fighter, entered into service. Before that, the HL-8 produced by CNNA, a company owned by industrialist Henrique Lage, had been the first three-engined airplane manufactured in Brazil. The HL-8 took its maiden flight on December 30, 1943. It resembled the Beechcraft C-45 and had two vertical stabilizers as well. We should also mention the Casmuniz 5-2 metallic twin-engined airplane, created and built in 1952 by Austrian designer Willibald Weber, based on small Aero 45 Chech twin-engines. Towards the end of 1954, after logging over 200 flight hours, the Casmuniz 5-2 prototype was sent to CTA for a test campaign, being certified in 1955. After the airworthiness certificate was issued, Cássio Muniz executives approached Cessna and proposed to build an assembly line in Brazil for the serial production of some Cessna single-engined aircraft types and Casmuniz 5-2 twin-engined airplanes. The proposal was refused, as the Americans were under negotiations to assemble their planes in Argentina, which was considered a more promising market. By the mid 1960's, a trend towards reducing the number of cities served by air transportation became evident. Since the end of World War II, hundreds of towns had been served by American aircraft, particularly the famous Douglas DC-3. This 30-seater could land on short unpaved runways with no or little flight support infrastructure.

In 1960, only 120 Brazilian cities were served by airlines, as opposed to 360 cities in the 1950's. For this reason, technicians of CTA's Instituto de Pesquisa e Desenvolvimento - IPD (Research and Development Institute) proposed a project to design a twin-engined turboprop airplane that could carry 20 passengers and operate in the conditions existing in most Brazilian cities. This group of technicians was formed basically by specialists who were undergraduates from the Instituto Tecnológico de Aeronáutica - ITA (Aeronautical Institute of Technology) and was led by the Brazilian Air Force Major Ozires Silva.In spite of overall skepticism, the Ministry of Aeronautics commissioned IPD in 1964 to conduct a study on the possibility of producing twin-engined turboprop airliners in Brazil. The Ministry intended to achieve two primary objectives: first, to design a modern and simple airplane to be produced in series in Brazil, and second, provide the Air Force with a versatile aircraft that fulfilled the Brazilian conditions. The group responsible for this study reviewed Fokker's old proposal to assemble the F-27 in Brazil, and also gave consideration to the Hawker Siddeley HS-748, the Dart Herald and the Convair 580. All these aircraft were considered too large and complex for Brazil's industrial capabilities. On the other hand, the Broussard, which had also been proposed, was too small and low tech. The solution was to create an intermediate native model.

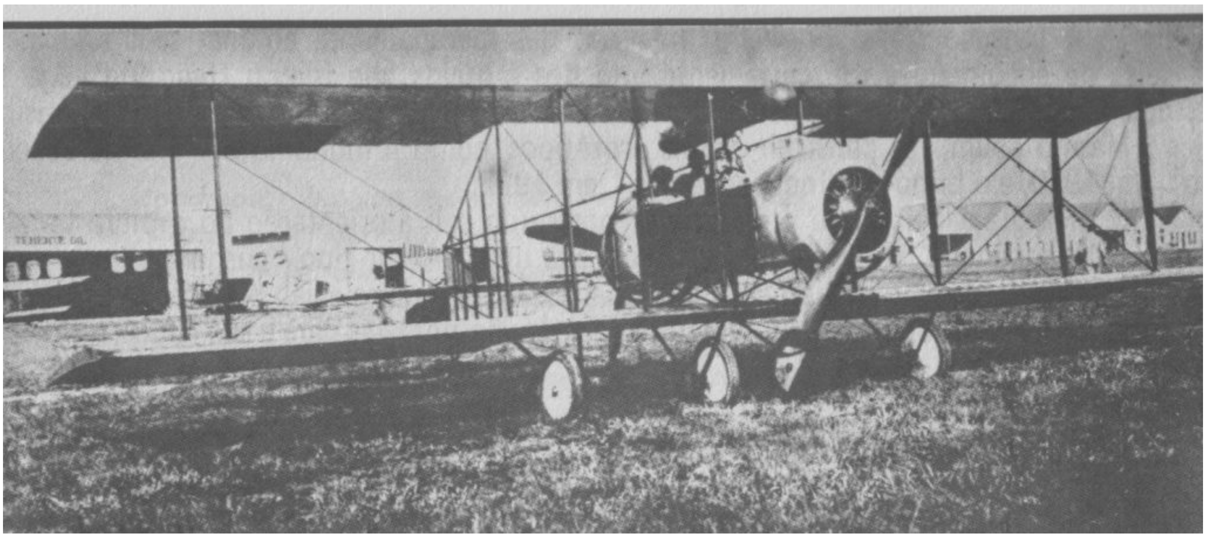

Fig. 23 – The twin-engined Independencia aircraft had an unusual configuration.

Fig. 24- IPD-6504 (EMB-100).

In early of 1965, during his visit to Brazil, Max Holste, a famous French engineer who manufactured aircraft, was approached by IPD Director, Engineer Ozires Silva, and then about 30 years old, who informed him about the plan to produce a Brazilian twin-engined aircraft. José Carlos Neiva, owner of Sociedade Construtora Aeronáutica Neiva, and his partner Joseph Kovacs, who had been involved in the T-25 Universal trainer design, went to São Paulo and brought Max Holste by car to São José dos Campos. First, Holste wanted to learn about CTA's real potential, as he did not believe in the Brazilian manufacturing capabilities. He then proposed the local production under license of the Broussard Major, a high-wing, piston-powered airplane. Instead of this, Holste got engaged in the design of the Brazilian twin-engined aircraft and formed a high-level Brazilian team. Brazilian Air Force officials believed Holste had come to Brazil in order to coordinate the retrofit of the Air Force fleet and were unaware that he was going to be the technical coordinator of a new airplane design project. Ultimately, the result was the design of the IPD-6504 airplane that was based on a simple concept: turboprop, metallic, low wing, retractable tricycle landing gear, maximum takeoff weight 4,500 kg, equipped with two Pratt & Whitney Canada PT6A-20 turboprop engines. On June 12, 1965, Aeronautics Minister Brigadier Eduardo Gomes signed the approval of the IPD-6504 project (**Fig. 24**), and in that same month, IPD's Aircraft Department started to construct a prototype.

It took 40 months to build the airplane, from initial studies to the maiden flight on October 22, 1968. The project demanded 110,000 design hours, including 12,000 manufacturing drawings, 22,000 hours of airframe and aerodynamics calculations, and 282,000 hours to manufacture the aircraft and its tooling. About 300 people from IPD/PAR alone were involved in the project during this period of time. In addition to the IPD/PAR team, other Aeronautics Ministry agencies, such as the Afonsos Airbase, Lagoa Santa Air force Maintenance Unit, and several industry companies, including Aerotec and Avitec, contributed for the success of IPD-6504's maiden flight. Finally, the IPD-6504 prototype took off from CTA's unpaved runway under FAB's colors, at 7:07 a.m., on October 22, 1968, piloted by Maj.-Eng. José Mariotto Ferreira and flight test engineer, Michel Cury. However, the first official demonstration flight of the IPD-6504, registered as YC-2130, did not take place before October 26, 1968. Unfortunately, a few days later, Major Mariotto died when testing a Uirapuru airplane. Michel Cury once remarked about the IPD-6504 flight:

"Although we were naturally worried about the flight, the plane was operationally normal. We had anticipated landing problems involving the propellers because one of the parts used in this operation failed to meet engine specifications. The flight, however, was full of surprises. The first one was a shower of burr being released from the electronic equipment panel and falling over the pilots' heads."

Later, Major Mariotto noticed that the trim tab commands were reversed. The commands, of course, had to be activated the wrong way, and that's how it was the whole flight. The flight was made under bad weather conditions and, at times, it seemed that it would be necessary to fly by instruments. When landing the airplane, the crew paid special attention to engine reversion to prevent jolts.

Fig. 25 – Bandeirante EMB 110 (bottom) and its inspiration (top), the Nord 262 airliner. The 29-seater Nord 262 high-wing monoplane is derived from the MH250 Super Broussard, which was designed by Max Holste.

On May 15, 1969, the first prototype, numbered YC-95 2130, that transported passengers for the first time on a demonstration flight over the city, including the Minister of Aeronautics Brigadier Márcio de Souza e Mello, the Mayor of Brasília, Wadjo Gomide, and the commanders of the 6o COMAR, Brasília Naval Command, and Planalto Military Command. President Costa e Silva decided to fly on Bandeirante on the spur of the moment, leaving security agents in panic, according to Ozires Silva's book *A Dream Takes Off*. The passengers of the next scheduled flights included the journalists invited for the occasion. Max Holste's work came to an end with the production of the first Bandeirante prototype. He would often clash with the Brazilian technicians. Still not believing Brazilians would be able to serially manufacture Bandeirante, Holste left the project team in 1969 and moved to Uruguay. After EMBRAER was established in August 19, 1969, other prototypes were produced. After a stretched version was developed, the serial production of Bandeirante started in the early 1970's.

7. The creation of EMBRAER

EMBRAER - Empresa Brasileira de Aeronáutica S.A., an incredible success story of a business, economic and technological winner. In the same way its predecessors, the EMB 110 Bandeirante and the EMB 120 Brasilia, the elegant 50-seater ERJ 145 has become a huge sales success. Approaching 1,000 deliveries, the ERJ 145 aircraft family includes the 37-seat ERJ 135 and the 44-seat ERJ 140. It should be pointed out that the number of units produced exceeded the entire British commercial jet production, from the Comet to the Avro RJX. An interesting aspect of EMBRAER's history is the fact that Bandeirante, its flagship product for many years, was created before the company was founded. Only after the Bandeirante performed its maiden flight in 1968 did the Brazilian government, spurred by its commercial possibilities, decide to establish EMBRAER on August 19, 1969, through a decree law passed by the Military Junta that governed the country at that time.

A series of modification were undertaken to transform the EMB-100 Bandeirante designed at CTA into an aircraft able to be serially manufactured. Its capacity was increased to 19 passengers; more powerful engines were fitted into the configuration; rounded windows replaced the original squared ones; and the configuration suffered a several aerodynamic improvements. Guido Pessotti led the team that conceived all modifications. The resulted configuration was marketed as EMB-110; the EMB-111 variant was later developed for maritime patrol.

The Brazilian aeronautical industry had to overcome several setbacks along its history before reaching the present level in which EMBRAER ranks among the world's major aircraft manufacturers. Less than four years went by from Santos Dumont's flight with his 14Bis in France to the production of the first wholly Brazilian airplane, the São Paulo monoplane, which first flew in January 1910; twenty-five years elapsed until the Muniz M-7 biplane became the first aircraft to be serially produced in the country by Companhia Nacional de Navegação Aérea (CNNA). After that, 33 long years went by before the foundation of EMBRAER, the first Brazilian aircraft manufacturer of technologically advanced products that represent the consolidation of the Brazilian aeronautical industry.

In order to have an idea of how long it took for the competitive Brazilian aeronautical industry to become established, look at the history of the first aircraft manufacturers in Europe and the United States. The French Gabriel Voisin started his career in aeronautics in 1903 by building gliders. In 1905, he founded the first world aircraft company together with Louis Blériot, but soon bought Blériot's share in the business. In association with his brother Charles, Voisin revamped the company, changing its name to Appareils d'Aviation Les Frères Voisin, and produced 75 airplanes by 1912. Henri Farman, one of the major French manufacturers of that time period, produced 12,000 aircraft during the First World War. The first American aircraft factory was founded in 1908 by Edson Gaulladet. Starting out as an aeronautical engineering firm, the Gaulladet Engineering Company was created in 1910. General Dynamics considers Gaulladet's company as one of its ancestors. The aircraft industry expanded a great deal during the two World Wars and the Cold War. Of course, other non-military factors have also contributed to the industry's technological development. When EMBRAER was created in 1969, commercial jets already dominated the large-capacity air travel segment. In the year before, the experimental airplane-rocket X-15 made its last flight. In two of its missions, the X-15 reached an altitude of 100 km, a manned-flight record only equaled in 2004 by Burt Rutan and his teams's SpaceshipOne mission. In other missions, the X-15 has reached the incredible speed of Mach 6.72, not yet surpassed by any other aircraft so far. Also in 1969, the Boeing 747, the Concorde supersonic, and the X-24A experimental aircraft took their maiden flights. Many people believed that faster airplanes would replace the Boeing 747. The Concorde, despite its wonderful technology and high speed, proved to be a commercial failure. The X-24 had no wings, and its own fuselage generated the necessary lift. In 1969, American astronaut Neil Armstrong walked on the Moon and ARPANET, the system that ushered in the Internet, was created.

The Brazilian aircraft industry took a long time to become globally competitive; an achievement made possible some time after EMBRAER was founded by building on the industry's past experience. Prior to this turning point, aircraft manufacturers and civil and military governmental agencies played an essential role in terms of training specialized workers, placing aircraft orders, obtaining financial incentives, as well as structuring and maintaining aircraft industry's activities in the country. In special, the creation of Centro Técnico de Aeronáutica (Aeronautical Technical Center) - later redesignated as the Centro Técnico Aeroespacial (Aerospatial Technical Center) - represented as one of the most important milestones in that direction. The existence of CTA enabled the nucleation of the country's aeronautical knowledge in working in a collaborative environment. The industrial ring around CTA promptly benefited from the knowledge and research being carried out there. Several aerospace companies started activities after CTA was created. Guedes Muniz, the designer of the Muniz M-7 airplane, the first to enter serial production in Brazil, was already aware of the need of an aerospace research center supporting aircraft manufacturers in the country. However, it was Brigadier Casimiro Montenegro Filho who envisaged the CTA final shape and structure. Montenegro also played the main role in turning CTA into reality.

8. Concluding Remarks

The Wright brothers were only able to publicly fly their airplane in May 1908, more than a year after Dumont's flight at Bagatelle, France. Their airplane suffered a series of modifications after Wilbur's stay in Europe, resulting in the Flyer A configuration, which was sold to the Armed Forces of the United States. At that time the Europeans were already flying long distances and their aircraft were also able to perform turns and several kinds of maneuvers. Convincing evidence that the Wrights actually flew in 1905 has yet to be presented.

Certainly, the masters behind Dumont's flight with 14Bis were the Voisin brothers. Their partnership with Dumont, who possessed good experience in integrating engines into airships, resulted in the successful 14Bis flights in 1906. The Voisin brothers with their aircraft company also enabled the start of the European aviation with the flights of Farman and Delagrange. That is an example that mutual help instead of lawsuits spurs the development of technology and progress of mankind.

There is a misconception in Brazil that the creation of ITA was entirely responsible for the foundation of EMBRAER. In this context, it is worth to say that the Brazilian government, and specially the military, had been prone to establish an indigenous aircraft industry in Brazil for a long time. Their efforts were not successful because they were supporting the design and manufacture of obsolete aircraft and taken into account only the domestic market. EMBRAER was successful because the Bandeirante after suffering modifications was a competitive product for the international market. Without intention, willingness, and investments the sole creation of an aeronautical course would be of no practical effect. "So sprach Guedes Muniz."

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