THE SANTOS-DUMONT LEGACY TO AERONAUTICS

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Abstract

Several pioneers have contributed to the aurora of aeronautics. Their contributions have ranged from simple ideas and early conceptions to proofs-of concept, prototypes, and aircraft, not all of them successful. It is not easy to attribute the invention of an aircraft to any particular inventor. However, by establishing some logical guidelines, it is possible to make a fair evaluation of the technical contributions given by a certain pioneer to the development and certification of a given type of aircraft. Under these logical guidelines, one can easily ascertain that the Brazilian Alberto Santos-Dumont pioneered the dirigible and the airplane, and gave technical contributions to the hot-air balloon and to the helicopter. His model 6 dirigible should be recognized as the first of such aircraft to be certified. His 14-bis airplane model should be recognized as the first of its kind to fly under certification rules. His Demoiselle models were the first airplanes ever to be produced in the scale of hundreds. Finally, through many actions and attitudes, he inspired people all around the world to study aeronautics, to build airplanes, and to fly them. In conclusion, Santos-Dumont must be recognized, among all aviation pioneers, as the one who provided the most relevant contributions to the advent of aeronautics in this planet.

1 Introduction

It is a natural human trend to look only at one’s own universe, limited by one’s own senses, times, and horizons, and to write history as the facts have been seen by one´s own eyes or heard by one´s own ears. In being as such, regarding the answer to the hypothetical question who invented the airplane, the answer might change a lot, depending on the person, the place, and the time.

For instance, without the preoccupation of trying to exhaust the issue of airplane primacy, let us consider a few cases.

In England, there are several well-versed aeronautical professionals that wouldn’t take more than a second to indicate George Cayley as the correct answer to the question. This is what has stated Ackroyd [1] in 2011, for example.

In 1990 the French celebrated the first century of aviation by recalling the flight attempts of Clément Ader’s airplane [2]. In the so-called Year of Ader, there was official celebration by the Historic Service of the French Air Force of the first take-off in the world of a motorized airplane [3].

If one asks the same question in Russia, the answer will certainly be Alexander Mozhaisky. At least this is what I heard several times there, in various Russian aerospace institutes and museums that I have visited myself since 1992.

The examples go on and on, depending on the country. In Australia, the inventor of the airplane is Lawrence Hargrave. In the United States, for sure, the Wright Brothers. In Germany, Otto Lilienthal. In Italy, the experts go as far as to nominate Leonardo da Vinci. Following this natural trend, every country has its own inventor of the airplane, with positions defended by ideas that range from solid technical grounds to pure patriotic feelings.

It is not our idea here to prove that the Brazilian answer is the correct – or the most correct. That presumption would be polemic, if not arrogant, to say the least. On the contrary, the idea of this paper is to lay solid technical grounds and let the conclusions of the reader emerge by themselves. The reader will be the ultimate judge.

First, we establish the logical rules for the discussion. Then, we describe the role of the aeronautical societies and the meaning of the certification rules. In the sequence, by using the established logical reasoning, we analyze the contributions of several aviation pioneers that were seminal to the advent of a given type of aircraft. To conduct a systematic and fair analysis, we have divided the discussion between lighter and heavier-than-air aircraft. In the end, we wrap up the results and come through with conclusions.

Every attempt is made to avoid any kind of bias and to be as precise as possible. Obviously, this work will be scrutinized by people with technical skills and open reasoning. Let this author's synthesis be evaluated with free and fair criticism.

This paper examines well-known historical facts and not so well-known technical facts regarding both lighter and heavier-than-air aircraft beginnings. The idea is to identify the main contributions to their development and fruition and the persons who were responsible for them. From this survey, one can naturally pinpoint the remarkable role of the Brazilian self-made engineer Alberto Santos-Dumont and his outstanding contribution to the aurora of aeronautics.

2 A Common Scenario

Let us define aircraft as a human-made device capable of taking-off by its own means, of traveling in the air describing a stable and somehow controllable path, of carrying a useful load, of landing in a safe fashion, and, finally, being able to repeat this sequence of events again and again.

One might argue that this definition is biased towards favoring one set of aviation pioneers against other set at the very onset of this discussion. To those who dispute the value of this definition, I would reply that it describes quite well and encompasses with reasonable generality the practical understanding of the concept of aircraft, as we see them operating today, more than a century from the advent of the airplane. This definition applies very well from balloons and dirigibles to sailplanes, airplanes, and helicopters. It includes, also, drones that deliver books or pizzas to customers and modern rockets that deliver packages to space stations and come back to land on Earth, with the purpose of being reused.

Following this definition, we have two main groups of aircraft: those whose main principle of functioning is based on having an average total density close to the air – called lighter-than-air aircraft (aerostats) – and those whose functioning resides on other means of lift, like having lifting surfaces and/or propulsion systems capable of withstanding the aircraft's weight – called heavier-than-air aircraft (aerodynes).

Every aircraft, before being recognized as such, should pass through the phases of conception, research and development (R&D), certification, production, and, finally, utilization. Furthermore, during the development phase, several research issues should be adequately considered regarding design, aerodynamics, materials and structures, propulsion, stability, control, systems, and flight mechanics, prior to some sort of airworthiness certificate being issued by some established and acknowledged technical authority.

3 Logical Guidelines

In this section we set foundations for the present study, meant to define when a certain type of aircraft may be considered fully developed and ready to be used by the general public.

For the stated purpose, our plan is to use here the NASA Technological Readiness Levels (TRL) concept [4] to evaluate the maturity of the aircraft project with time. These levels, as seen by the US Department of Defense (DoD) are presented as follows [5]:

1. Basic principles observed and reported;
2. Technology concept and/or application formulated;
3. Analytical and experimental critical function and/or characteristic proof of concept;
4. Component and/or breadboard validation in laboratory environment;
5. Component and/or breadboard validation in relevant environment;
6. System/subsystem model or prototype demonstration in a relevant environment;
7. System prototype demonstration in an operational environment;
8. Actual system completed and qualified through test and demonstration; and
9. Actual system proven through successful mission operations.

In our logical groundwork, an aircraft will be admitted ready when reaching levels 8 or 9 and/or entering into serial production.

For example, in Brazil we celebrate the Aeronautical Industry Day on every October 17th. This date recalls the year of 1935, when, on Campo dos Afonsos, located in the outskirts of Rio de Janeiro, happened the first flight of the first Brazilian designed airplane that entered into serial production (Figure 1). The designer was the then Army Captain Antonio Guedes Muniz, an aeronautical engineer educated in France. The airplane was named Muniz M-7. According to the records, 27 of them have been manufactured [6].

Fig. 1 – Antonio Guedes Muniz and his airplane M-7, the first of Brazilian design to enter into serial production (first flight in October 17th, 1935).

Let us now consider briefly the relation between aeronautical societies and certification. Every new subject is initially dealt with by a single individual or by a small group of individuals. When the subject becomes mature enough, it is quite common that a greater number of individuals get together and create a sort of association to deal with common issues and interests. Aeronautics followed exactly the same natural path.

The first association created to deal with aeronautics was officially the Aeronautical Society of Great Britain. Founded in 1866, it is now known as Royal Aeronautical Society (RAeS) [7]. To prove the power of gathering people with common goals, two years after its creation, the Society was able to put up an exhibition of aviation technologies in the Crystal Palace in London.

When people interested in the same subject get together, there starts the convergence of ideas towards standardization and creation of certification rules. Certification is meant to make safer the operation of aircraft for those who fly, either as crewmembers or passengers, or also for those who stay on ground, but might suffer the effect of aircraft operational problems and accidents.

Under the orientation of the French aeronautic enthusiast Octave Chanute, in the year 1895 started in the United States the publication of *The Aeronautical Annual*. The ideas of aeronautics started to spread faster, benefiting all persons interested in flying no matter what sort of aircraft they were willing to use. The *Aéro-club de France* was created in 1898, the first organization of its kind totally devoted to aeronautical issues with focus on piloting. Officially, it was the first organization of its kind to encourage aerial locomotion.

Organizations like the Aeronautical Society of Great Britain and the *Aéro-club de France* were precursors of certification organizations like the Federal Aviation Administration (FAA - 1958) in the United States – formerly Civil Aeronautics Authority (CAA - 1938) – and the European Aviation Safety Agency (EASA), which was preceded by the Joint Airworthiness Authorities (JAA - 1970) in Europe. If, today, aircraft are designed having certification rules as guidelines, aircraft of the past were evaluated by rules created by these pioneering organizations.

Admitting by hypothesis the definition of aircraft given in the last section, an aircraft will be considered ready for use, from the practical standpoint, after checking the following three milestones, which are pragmatic results of an aircraft being at TRL 9:

1. *open, public demonstration of flight* – requirement of levels 7 and beyond;

2. *observation of a set of known rules or specifications to be met during the flight* – the certification requisites by themselves; and

3. *existence of an institution capable of certifying the flight demonstration* – the fully recognized aviation authority.

Now, let us put the logical guidelines presented here to a test, by considering both lighter and heavier-than-air aircraft development and their related historical and technical features.

4 Lighter-than-air Aircraft (Aerostats)

The first public demonstration of a model of hot-air balloon has been made by a Brazilian Jesuit priest called Bartolomeu Lourenço de Gusmão. The day was August 8th, 1709, in Lisbon, before the court of the Portuguese King João, the Fifth, who had awarded Gusmão the first patent for a "device to navigate through the air" on April 19th of the same year. These are the known records. Very probably, there might have been older public demonstrations of hot-air balloons in China, but the records have to come forward and be presented to the scientific community for acknowledgement.

Well-known records in history are the first public presentations of the real sized hot-air and gas balloons, starting both in 1783. The French brothers Joseph-Michel and Jacques-Étienne Montgolfier, paper makers, pioneered the hot-air balloon, and the French scientist Jacques Charles the hydrogen balloon. These historical achievements preceded the creation of the certifying organizations. The balloons came to exist before the rules. Therefore, they verify just the first milestone established in the last section.

Alberto Santos-Dumont first came to know about the existence of a hot-air balloon in 1888, with the age of 15, in an aeronautic exhibition in the city of São Paulo. Soon after, his father, a rich coffee farmer and engineer, sent him to Paris with the orientation of studying physical sciences. His father added the following advice for the young man: the future is in Mechanics.

When Santos-Dumont made his first balloon flight in Paris, in March 23rd, 1898, at the age of 24, as a curious passenger, balloons were already well-developed aircraft. On May 30th of the same year he faced his first solo flight during the night, with thunderstorms. In the next month he started developing even further his pilot skills by, in the condition of commander, to transport a couple of passengers on a flight in a rented balloon. Figure 2 shows him ready to take aloft several passengers for a flight experience.

Fig. 2 – Alberto Santos-Dumont taking passengers for a balloon ride in 1898.

After proving himself a skilled balloon pilot, in the sequence he made several contributions to this kind of machine. Using new, lighter materials, in 1898 he developed the smallest yet practical hot-air balloons of that time, the models he named *Brésil* (Figure 3) and *Amérique*. With these models he won the award offered by the *Aéro-club de France* – the oldest aeronautical club in the world – for the study of atmospheric currents, reaching the highest altitudes and staying aloft for more than 22 hours. Even the most experienced balloon experts were astonished by these results.

Fig. 3 – Santos-Dumont flying the balloon *Brésil* in 1898.

But the greatest challenge of the time was the development of the steered balloon or dirigible aircraft. There were already dirigibles at the turn of the 19th century. The French Henri Giffard had been flying his dirigibles (airship) since 1852. He could make curves and circles. However, the aircraft steam engine was heavy and he was unable to complete long circuits facing strong winds.

In 1883, the French Gaston Tissandier was the first aeronautical designer to use an electric engine to power his aircraft. However, the 1.5 HP engine proved very weak for the task of providing controllability to the airship. In the next two years the French Army officers Charles Rennard and Arthur Krebs were much more successful with the dirigible *La France* with an 8.5 HP electric engine.

The German Count Ferdinand von Zeppelin started developing rigid dirigibles in 1898 powered by gasoline engines. However, his first successful models LZ-3 and LZ-4 came out only after 1907.

Santos-Dumont innovated and was the first designer to be successful using a gasoline engine to propel an airship, instead of an electrical or steam engine, despite the risks of having hydrogen deposits around in the aircraft envelope. The experts considered that sparks coming from the engine would ignite the hydrogen used to make the airship a floating device. Santos-Dumont ignored much of the warnings and, with courage, decided to go ahead with this design decision.

In fact, several accidents happened, taking sometimes the life of aviation pioneers. For instance, on May 12th, 1902, the Brazilian aeronaut Augusto Severo and his French mechanic Georges Saché died while flying over Paris in an accident with their airship called *Pax*. This accident got a lot of publicity and ended up transformed into a silent film, calling even more attention to aeronautics.

For the first time in history, certification type rules came into effect in the case of the airship. The *Aéro-club de France* gave public notice of a competition to prove the airship dirigibility. The objective of the challenge was to complete a round-trip travel from the Saint-Cloud field to the Eiffel Tower in less than 30 minutes. This challenge was named after Deutsch de la Meurthe, the Oil King in Europe, a member of the *Aéro-club* and prize sponsor. At least a dozen candidates were able to make attempts to win this prize of 100,000 francs.

Santos-Dumont was conducting experiments with airships since 1898, following the end of his balloon pilot career. Along the year 1901, since July, he made several attempts to win the prize with his model number 5. In August 8th, a flight with model 5 almost ended in disaster, with the aviator being rescued on the roofs of the *Trocadero Hotel* by Paris firemen. Finally, in October 19th, 1901, with his model number 6, he was able to fulfill all the conditions established for the challenge. Figure 4 shows the moment he was making a turn around the Eiffel tower, midway for the programmed closed circuit and victory.

This conquest should be understood, from the historical standpoint, as the certification of the dirigible. Considering the guidelines presented here, there was a competition, there were known rules, there were several competitors, there were numerous public flight attempts, and there was a technical committee from the *Aéro-club* to judge the results.

Besides being the first aeronaut to use with success combustion engines to propel the airship, there were other technical achievements obtained by Santos-Dumont that deserve being noted:

- With a sequence of models, he matured the airship technology through all TRL until 9. He won the prize with model number 6, but continued improving the invention. In total, he made 11 airship models of increased sophistication, varying in size from the small *Baladeuse* number 9 to the large *Omnibus* number 10.
- He created the first hangars in the world, practical production of hydrogen, and all the logistics required for the aircraft operation.
- With this sequence of efforts, he grasped the full meaning of the concepts of aircraft equilibrium, stability, and control. He would use this knowledge and experience to speed up the development of heavier-than-air aircraft in the years to follow.

Fig. 4 – Santos-Dumont making a turn around the Eiffel Tower with his airship number 6 in October 19th, 1901.

Santos-Dumont airships were very stable and controllable aircraft. Several aviation pioneers were unable along their lifetimes to obtain a full understanding of these concepts, their aircraft being later proven in studies to be static and dynamically unstable. Besides, some pioneers have used in their machines awkward, not anthropomorphic controls. Santos-Dumont showed the contrary, excelling in finding the easiest way to control his flying machines.

After having developed this special capability, he took the 7-year old boy Clarkson Potter to fly with him with his airship number 9 in June 26th, 1903. Three days later, after some theoretical ground instruction, he allowed the Cuban lady Aída de Acosta to fly solo the same aircraft. He followed her flight by bicycle from the ground, giving her instruction with signals. Some interesting revelations about these happenings can be found in the books by Hoffman [8] and Drumond [9].

5 Heavier-than-air Aircraft (Aerodynes)

Starting in 1903, Santos-Dumont made a transition from aerostats to aerodynes. This transition was not abrupt, in the sense that he was still developing aerostats in 1907, like his hybrid airship model number 16, while he was already making progress of his airplane model number 11 and of his helicopter model number 12 in 1905.

In 1903 the *Aéro-Club de France* launched another challenge: the *Coupe d'Aviation Ernest Archdeacon*. Despite the rumors that the Wright Brothers had flown an airplane in America in the end of that same year, no public evidence of this result was known or granted faith by most aviation enthusiasts in Europe in the next years. The Archdeacon Prize was meant to celebrate the first powered flight of an airplane. Again, there was a competition, some rules to be followed, several candidates, numerous public flight attempts, and a technical committee to judge the results.

For sure, at that time no one knew exactly how to fly a heavier-than-air aircraft nor with which type of aircraft this task could be done. Some pioneers were seriously experimenting with flapping wing aircraft, the so-called ornithopters. Others, including Santos-Dumont, conducted developments of rotary-wing machines. His project number 12, in 1905, considered an aircraft with two contra-rotating sets of rotor blades propelled by a 24 HP engine. However, he soon realized that technologies were not ripe enough at that time for the fruition of this kind of aircraft. Apparently, he questioned mainly the poor performance of the power transfer from the engine to the rotor blades. Figure 5 shows the aviator besides his model 12 in development.

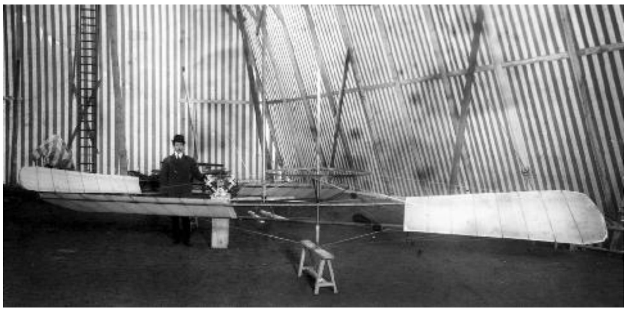


Fig. 5 – Santos-Dumont alongside his model number 12 – soon to be abandoned – a helicopter in 1905.

The technologies that were missing at that time were those linked to the following main issues:

1. How much power is needed for such an aircraft? If there was no known answer for a fixed-wing aircraft, for a rotating-wing one the answer was much tougher to come by.

2. Which aircraft configuration to use for practical compensation of the torque coming from the rotors?

3. What are the aerodynamic characteristics of rotating wings? If the answer was unknown for the aerodynamics of fixed wings, try to imagine turning them around an axis.

4. How to get the helicopter trimmed and which are its stability characteristics following any perturbations?

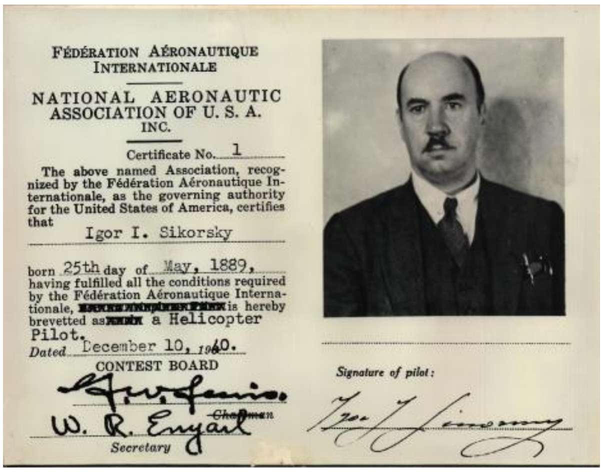
5. How to control such a machine out from the ground and keep it flying smoothly in the air?

6. What are the proper safety measures to take in case of engine failure?

7. Last but not least, what is the purpose or utility of such an aircraft?

In 1905 there were too many questions regarding rotary-wing aircraft and not as many answers. In the next four decades, many pioneers dedicated their time, energy, and money trying to solve these questions. Excluding from the list, for obvious reasons, the Italian Leonardo da Vinci, who coined the word helicopter, from wings in form of helix, among the most prominent names are the Russian-American George de Bothezat, the Spanish Juan de la Cierva, the French Louis Bréguet, and the German Heinrich Focke.

Although these pioneers and many others have addressed the questions presented before, none of them was able to make the helicopter technology mature enough to reach TRL number 9 prior to a Russian-American named Igor Sikorsky. Starting as a fixed-wing airplane designer in Russia, Sikorsky ended up producing in the United States the first helicopter to enter into serial production, the model H-4 in 1944. Besides, he was the first helicopter pilot ever to get a license, as shown in Figure 6.



FÉDÉRATION AÉRONAUTIQUE INTERNATIONALE

NATIONAL AERONAUTIC ASSOCIATION OF U. S. A. INC.

Certificate No. 1

The above named Association, recognized by the Fédération Aéronautique Internationale, as the governing authority for the United States of America, certifies that

Igor I. Sikorsky

born 25th day of May, 1889, having fulfilled all the conditions required by the Fédération Aéronautique Internationale, [redacted] is hereby brevetted as [redacted] a Helicopter Pilot.

Dated December 10, 1940.

CONTEST BOARD

Chairman

W. R. Enyart

Secretary

Signature of pilot:

Fig. 6 – Igor Sikorsky helicopter improvised pilot license. Credit: Igor I. Sikorsky Historical Archives.

Santos-Dumont transition from aerostats to aerodynes was very quick, faster than anyone could realize. He drew much criticism from those who did not understand this change. In 1905, he was already known all around the world as an airship man, for having earned the Deutsch Prize. How to explain his rapid and successful change from one to another kind of aircraft?

The explanations reside in his accumulated knowledge, experience, and intuition. First, he was very well acquainted to all sorts of engines. Having worked all along his youngerhood with steam engines and several types of machines in his father's railroads and farms, he became quite skilled as a mechanic. In Paris, along his aviation development years, he was known to buy several engines from manufacturers, making changes and adaptations in order to make them lighter or more powerful. Second, along the development of his airship models, he made all his propellers and adapted them to the engines so that he could transform engine into thrust power with minimum losses.

Along with this work involving engines, propellers, and the adaptations between them, he learned in practical terms how to compensate torques and how to configure an aircraft for best combination between lift and power. At that time, power was a luxury that very few aviators could get, at least not as much as they wanted.

To better understand this statement, let me consider a real case. In Brazil, since 1988, a Santos-Dumont enthusiast, now a retired Air Force Colonel named Danilo Flores Fuchs, tried to build replicas of Santos-Dumont´s 14-bis model. He flew them many times, in dozens of places, mainly in 2006, during the celebration of the first centenary of aviation in the Brazilian style.

In 1989 Col Fuchs [10] confided me that after trying to reproduce the machine as exactly as possible, according to the original plans, with the same configuration, controls, structure, aero-dynamics, and motorization, he felt a pitching down trend whenever powering up the airplane in the air. Then, by looking carefully to the old, original photos of the 14-bis, he realized that the thrust line of the propeller was not perfectly aligned with the fuselage waterline. In fact, there was an angle between them, thrust line pointing up relative to the waterline. The discovery was that Santos-Dumont was using part of the engine power to produce lift and to compensate for changes in torque. After making this subtle change of angle, the pitching down trend disappeared and his airplane showed much better handling qualities.

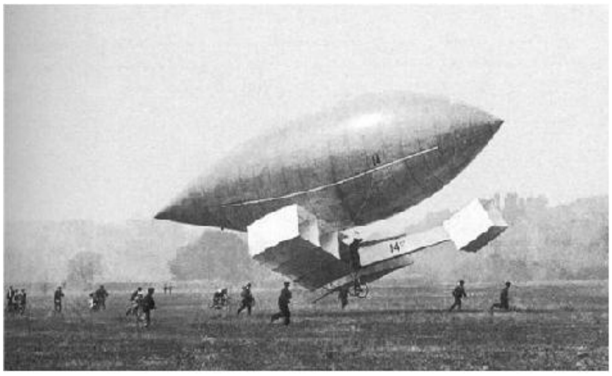


Fig. 7 – Santos-Dumont attempts of trimming, and testing the 14-bis model stability and control.

Best explanations for Santos-Dumont´s fast transition between aerostats and aerodynes go well beyond those already presented here. In Figure 7 he appears using dirigible number 14 as a lifting device to check on the characteristics of trim, stability, and control of the airplane he named 14-bis. Note that in the photo there are no strings attached. The whole assembly is fluctuating or "flying", thus, allowing verification, among other parameters, of the aircraft weight, center of mass, and reaction to control surfaces movements. This exact image of models 14 and 14-bis together has been taken in Brazil as symbol for the flight tests activities within the Brazilian Air Force. Therefore, Santos-Dumont is considered our first and most honored test pilot.

Other important contribution to aeronautics was Santos-Dumont's handling and application of new materials in aircraft construction. He started using in his balloons Japanese silk for the envelope and bamboo for the gondola. His airships used the same materials in their semi-rigid type designs. This trend continued in the design of his airplanes. Being shorter than 5'5'' and weighing less than 110 pounds, savings in aircraft total weight, pilot included, helped a lot in reducing his aircraft weight/power ratio and in improving his aircraft performance.

Turning his attention to fixed wing aircraft, Santos-Dumont first developed a monoplane glider and named it model number 11. The idea was to take-off from the water, using fluctuators instead of landing gears, and having a motorboat to tow it. As later development, he planned to install two propellers, one in each wing. According to Drumond [9], the tests on the water made him confident that the wings could generate enough lift, provided the speed of the aircraft were sufficiently high. However, he soon forgot the idea of going forward with this model 11 because he realized its poor stability characteristics.

With model 14-bis, Santos-Dumont won the *Aéro-club de France* Archdeacon Prize twice in 1906, first on October 23rd, by breaking the 25 meters flight length, and second on November 12th, by breaking the 100 meters limit. His flights were all public, on the Paris Bagatelle field, including aircraft take-off, sustainable flight, and landing by its own means. Two years later, in Paris, the first Wright Brothers public European flight demonstrations still required the assistance of catapults for take-off.

This is the right place to present a technical curiosity about these two flights and prizes. Figure 8 shows a photo of the October flight and Figure 9 of the November flight. By comparing them, there stands an interesting difference. During the October trials, Santos-Dumont noticed a lack of lateral-directional stability of the airplane. To solve this problem, he added two control surfaces, each of them near the end of the wing, inside the two most exterior Hargrave boxes.

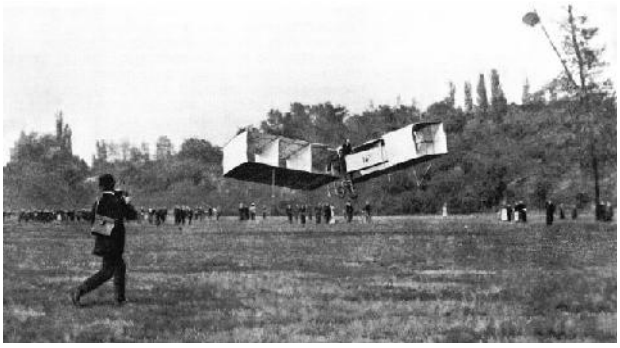


Fig. 8 – The October 23rd flight.

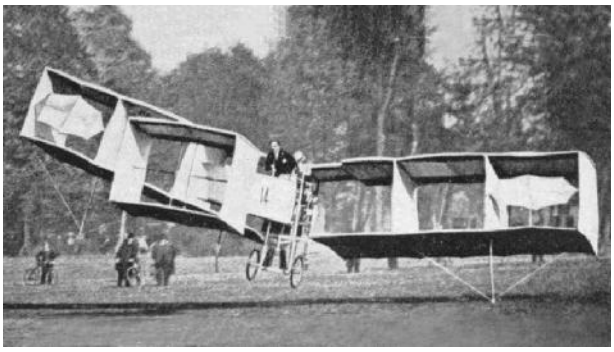


Fig. 9 – The November 12th flight.

Interestingly enough, in the years to come, aviators Henri Farman in France and Glenn Curtiss in the United States both claimed having been inventors of the ailerons. In the first case, Farman was contemporary and colleague of Santos-Dumont in the *Aéro-club*. In the second, roll control was subject of judicial dispute between Curtiss and the Wright Brothers over the wing-warping scheme.

Records of the Archdeacon Prize show another curious detail. Since 1903 several candidates were making attempts to fly, none of them successful. For certification purposes, a committee from the *Aéro-club* was required to witness the flight. In the October 23rd flight the committee wasn't there, at least the full committee. After having heard the news that Santos-Dumont had indeed flown, the committee agreed to show up in full for the November 12th attempts. The result was registered in the *Aéro-club* records and engraved in stone, on the flight place, as appears in Figure 10.

Fig. 10 – Monument in Bagatelle Field, Paris, France.

Translating directly from the French:

Here, on November 12th 1906,
under the control of the Aéro-club de France,
Santos-Dumont has established
the first world aviation records:
Duration 21 seconds and 1/5
Distance 220 m

So was recorded the first certified flight (TRL 8) of an airplane on Earth.

In the book *Navigating the Air – A Scientific Statement of the Progress of Aeronautical Science up to the Present Time*, edited in May of 1907 by The Aero Club of America, one can find the following excerpt authored by Carl Dienstbach in original English [11]:

> *So the present day is as yet that of the air-ship proper. The aeroplane, with its greater possibilities of speed, economy and practical usefulness is still hidden below the horizon, in spite of the tremendous impetus the Wright Brothers and Santos-Dumont has given to its advancement. Santos-Dumont's was the first entirely public demonstration of man-flight without gas support – some 300 yards.*

By this statement, one can understand that the airship was already a matured system (TRL 9), while the airplane was still on the works. Besides, it became demonstrated by aviation authorities in 1907 that Santos-Dumont´s flight tests were all public, fulfilling the certification requirements.

As innovation, the airplane was incomplete by the 14-bis model. The completion (TRL 9) came with the next of Santos-Dumont's achievements. In the 1907-1909 period, he worked on projects 19 through 22, developing several versions of a monoplane, which came to be known all around the world as *Demoiselle*. With structure made of bamboo and silk, the aircraft wings had some transparency, resembling those of a dragonfly, from where she derived its French name.

Flying the *Demoiselle* in Paris and surroundings gave Santos-Dumont even greater fame. The well-known airship man had become an airplane man (Figure 11). He was awarded the first airplane pilot license by the *Aéro-club de France*. Besides establishing the first known records of flight time and distance, it became his the first record of airplane speed: 96 km/h.

Fig. 11 – Taking the *Demoiselle* for another flight.

Having never looked for protection to his intellectual property, Santos-Dumont generously distributed *Demoiselle* plans to whoever asked them. The result was the dissemination of the aeronautical knowledge world widely through the production of hundreds of aircraft in different countries like France, England, Netherlands, and United States. See, for instance, Wier [12].

6 Legacy as a Public Policy Maker

Santos-Dumont stopped flying in the beginning of 1910, at the early age of 36, due to an accident with the Demoiselle. However, he continued interested in aeronautics until his death in 1932. He continued to frequent the *Aéro-club de France* and to confer with his fellow aviator friends.

He wrote two books. During his aviator life phase, he wrote in French *Dans L'Air*, translated into English as *My Airships – The Story of My Life*, and into Portuguese as *Meus Balões* (1904) [13]. But it was in his post-aviator life phase (1918) that he wrote his most important source of inspiring ideas, the book – in Portuguese – *O Que Eu Vi, o Que Nós Veremos* (*What I Saw, What We Will See*) [14].

From his ideas, two public policies have been generated: the preparation of human resources in aeronautics and the technological independence. These ideas were used, three decades later, by Air Marshall Casimiro Montenegro Filho to create the Technological Institute of Aeronautics (ITA) [15]. Engineers graduated at ITA, two decades later, initiated Embraer. In recognition for his outstanding contribution, ITA has posthumously awarded Santos-Dumont the *Honoris Causa* Doctor degree in Aeronautical Engineering shown in Figure 12. So, his legacy goes on, lingering into eternity.

REPÚBLICA DOS ESTADOS UNIDOS DO BRASIL
MINISTÉRIO DA AERONÁUTICA
CENTRO TÉCNICO DE AERONÁUTICA

Instituto Tecnológico de Aeronáutica

Diploma

O Reitor do Instituto Tecnológico de Aeronáutica, no uso de suas atribuições, à vista da decisão unânime da Congregação, em sua 49ª Reunião ordinária de 29 de junho de 1956, confere, pelo presente, ao pioneiro da aeronáutica

Alberto Santos-Dumont

nascido a 20 de julho de 1873 e falecido a 23 de julho de 1932, natural de Minas Gerais - Brasil - o título póstumo, "Honoris Causa", de

Doutor em Engenharia Aeronáutica

em reconhecimento de sua contribuição original para o desenvolvimento da ciência e da técnica aeronáutica, como inventor, projetista, construtor de aeronaves e de protótipo de avião produzido industrialmente, a fim de que, também sob êsse aspecto, sua memória possa ser reverenciada.

São José dos Campos, 23 de outubro de 1956

Diretor Geral

Reitor Int.

Fig. 12 – Diploma of Doctor *Honoris Causa* in Aeronautical Engineering – ITA – 1956.

7 Conclusions

From the practical standpoint, in our planet aviation started in France and the *Aéro-club de France*, in Paris, was its embryo. Santos-Dumont was there, in 1898, as one of its founders [16].

As proved here, Santos-Dumont is, among all aviation pioneers, the only one who designed, developed, and fully tested, as engineer and pilot, both aerostats and aerodynes, balloons, dirigibles, gliders, airplanes, and helicopters. In the period of less than 12 years, from 1898 to 1910, he worked on 23 very different aircraft, with an average of two projects per year. His productivity as aeronautical designer, compared to any other contemporary designer, was simply unsurpassable.

He was responsible for the first certified flights of the airship and of the airplane. It was his *Demoiselle* the first aircraft to enter in serial production, thanks to his generous and unrestrictive donation of intellectual property rights. Finally, he gave solid basis for the policies that ended up introducing modern aeronautical industry in Brazil and abroad. No other aviation pioneer has left so comprehensive and sizeable legacy to humankind. Therefore, he deserves full recognition for his legacy and a very special place among all persons having passion for aeronautics.

References

[1] Ackroyd, J. A. D. Sir George Cayley: the invention of the aeroplane near Scarborough at the time of Trafalgar. *Journal of Aeronautical History*, Paper No. 2011/6.

[2] Ader, C. *L'année Ader - Centenaire du premier décollage au monde d'un avion a moteur - 1990.* Available in https://www.amazon.fr/CLEMENT-ADER-CENTENAIRE-PREMIER-DECOLLAGE/dp/B00BBIUH0I, broché, access in July 20th, 2018.

[3] Ader, C. *L'Aviation millitaire.* 2nd ed. (1990). Available in https://www.ebay.fr/itm/CLEMENT-ADER-Laviation-militaire-Reedition-du-centenaire-1890-1990-/232827273307, access in July 20th, 2018.

[4] Mankins, J. C. *Technology readiness levels: a white paper*. NASA Office of Space Access and Technology, Advanced Concepts Office, 1995.

[5] Wikipedia. *Technology readiness level.* Available in https://en.wikipedia.org/wiki/Technology_readiness_level, access in July 20th, 2018.

[6] Brandão, M. P. *Critical factors for consolidation of the Brazilian aeronautical industry.* In First National Seminar of the Brazilian Aviation History. Universidade da Força Aérea, Rio de Janeiro, 2012 (in Portuguese).

[7] Wikipedia. Royal Aeronautical Society. Available in https://en.wikipedia.org/wiki/Royal_Aeronautical_Society, access in July 20th, 2018.

[8] Hoffman, P. *Wings of madness – Alberto Santos-Dumont and the invention of flight*. Theia, New York, 1st edition, 2003.

[9] Drumond, C. D**.** *Alberto Santos-Dumont: new revelations*. Editora Cultura, São Paulo, 2009 (in Portuguese).

[10] Fuchs, D. F. Private communication. São José dos Campos, São Paulo, Brazil, 1989.

[11] The Aero Club of America. *Navigating the air – a scientific statement of the progress of aeronautical science up to the present time*, Doubleday, Page & Company, New York, 1907.

[12] Wier, S. *Superbly small: the Demoiselle airplanes of Alberto Santos-Dumont, 1907-1909.* Available in http://www.westernexplorers.us/Demoiselle-original-history.pdf, access in July 20th, 2018.

[13] Santos-Dumont, A. *Dans l´air*. 1904. Available in https://ia801407.us.archive.org/28/items/danslair00santgoog/danslair00santgoog.pdf (in French original), http://www.gutenberg.org/ebooks/42344 (in English), http://www2.senado.leg.br/bdsf/handle/id/530469 (in Portuguese), access in July 20th, 2018.

[14] Santos-Dumont, A. *What I saw, what we will see*. 1918 (original in Portuguese). Available in http://www.portugues.seed.pr.gov.br/arquivos/File/leit_online/santos_dumond.pdf, access in July 20th, 2018.

[15] Wikipedia. Technological Institute of Aeronautics – ITA. Available in https://en.wikipedia.org/wiki/Instituto_Tecnol%C3%B3gico_de_Aeron%C3%A1utica, access in July 20th, 2018.

[16] Aéro-club de France. *Les fondateurs.* Available in http://www.aeroclub.com/aecf-de-1988-a-nos-jours, access in July 20th, 2018.

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