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Philosophy and Ethics of Aerospace Engineering

António Luis Martins Mendes

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Orientador: Prof. Doutor Jorge Manuel Martins Barata

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Dedicatória

Gostaria de dedicar esta tese a minha Avó Rosa e aos meus Pais por acreditarem em mim e pelo apoio estes anos todos desde a primeira classe até agora.

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Resumo

A Engenharia é uma atividade humana reconhecida num determinado período da história (séculos XVII e XVIII), quando alguns militares projetaram, construíram, operaram e mantiveram fortificações e máquinas de guerra e, em seguida, essas atividades foram transferidas para aplicações não militares. A Engenharia continuou a mudar geográfica e socialmente e atualmente tem uma abrangência extremamente ampla e a sua relevância não é apenas baseada em tecnologia. No entanto, o seu papel na tecnologia é decisivo, pois é em grande parte pela tecnologia que a sociedade atual mantém sua coerência. A Filosofia da Tecnologia tem estado particularmente atenta ao impacto da tecnologia na sociedade e na cultura, mas não na própria tecnologia. Na verdade, a Filosofia não deu uma atenção adequada à engenharia. Pelo contrário, ao menos desde a década de 1960, membros da comunidade filosófica têm acusado os engenheiros de poluir o mundo natural, transformando o clima, fazendo produtos de consumo inúteis, etc. Somente em 1994 surgiu um novo ramo da Filosofia da Tecnologia que é se preocupa, também, com a própria tecnologia, e pode ser chamado **Filosofia de Engenharia** da Tecnologia (por contraponto à **Filosofia de Humanidades** da Tecnologia, versando apenas os aspetos das Humanidades – *Humanities Philosophy of Technology*) ou Filosofia e Ética da Engenharia. Trata-se de uma nova forma de olhar através da Engenharia, que não só considera os aspetos éticos, mas também muitos outros temas modernos que estão sendo transformados por criações técnicas como os novos existencialismos de projeção de riscos, redes informáticas, realidade virtual, sensação e perceção transumana e remota, apresentações gráficas e análise de probabilidades, sítios de internet interativos, alimentação, alojamento, transporte, comunicações, economia, etc.

O presente trabalho começa com uma expedição à história da Engenharia Aeronáutica em paralelo com a Filosofia e Ética, a fim de demonstrar a relação entre eles. Esta tese destina-se a mostrar a ligação entre a engenharia Aeroespacial / Aeronáutica e o crescimento da economia mundial (ou falta dela!). Isto é feito analisando alguns dados econômicos em termos de impacto mundial, bem como os aspetos sociais relevantes, tais como os salários da indústria de aviões nos Estados Unidos, França e Brasil, e sua relação com o rendimento da empresa e país. Estes países foram selecionados devido ao constante aumento de equipamentos de última geração comprovados em empresas como Boeing, Airbus e Embraer.

Palavras-chave

Filosofia, Ética, Aerospacial, Aeronáutica, Engenharia, Sociedade.

Abstract

Engineering was a recognized human activity at a certain period of the history (17th / 18th centuries) when some militaries designed, constructed, operated, and maintained fortifications and engines of war, and then those activities were transferred into non-military applications. Engineering has continued to change geographically and socially and presently is extremely broad and its relevance it's not solely technology based. However, its role in technology is decisive since is largely by technology that current society keeps its coherence. Philosophy of Technology has particularly attentive to the impact of technology on society and culture, rather than with technology itself. Actually, Philosophy has not paid adequate attention to engineering. On the contrary, at least since the 1960s, members of the philosophical community have been accusing engineers of polluting the natural world, transforming the climate, making useless consumer products, etc. Only in 1994 a new branch of Philosophy of Technology has emerged that is concerned with the technology itself, and may be called Engineering Philosophy of Technology or Philosophy and Ethics of Engineering. This is a new way of looking through engineering, that not only considers the ethical aspects but also many other modern issues that are being transformed by technical creations such as new existentialisms of risk projection, electronic networking, virtual reality, trans human and remote sensation and perception, graphic media presentations and probability analysis, interactive internet web sites, food, housing, transportation, communications, economics, etc.

The present work starts with an expedition to the history of the Aeronautical Engineering in parallel with the Philosophy and Ethics in order to demonstrate the relationship between them. This thesis is intended to show the link between the aerospace/aeronautical engineering and world-wide economy growth (or lack of it!). This is done by analyzing some economic data in terms of world impact as well as the relevant social aspects such as the salaries of the airplane industry in the United States, France and Brazil, and their relation to the company income and country. These countries were selected due to their constant increase in state-of-the-art equipment proven in companies like Boeing, Airbus and Embraer.

Keywords

Philosophy, Ethics, Aerospace, Aeronautical, Engineering, Society.

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Nomenclature

CG	Center of Gravity
EASA	European Aviation safety Agency
ECOSOC	Economic and Social Council
EU	European Union
FAI	Fédération Aéronautique Internationale
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCL	Flight Crew License
HP	Horse-Power
ICAO	International Civil Aviation
JAA	Joint Aviation Authorities
JAR	Joint Aviation Regulations
NASA	National Aeronautics and Space Administration
PICAO	Provisional International Civil Aviation
US	United States
USA	United States of America
WWI	World War I
WWII	World War II

Chapter 1. Introduction

1.1. Motivation and Scope

Engineering and Philosophy are typically conceived as two mutually exclusive domains.

The perspective of some engineers and philosophers is even worse. Engineering is commonly divided into a number of different branches such as civil, mechanical, electrical, computing, etc. The same situation occurs with Philosophy. It too includes different branches: logic, epistemology, metaphysics, ethics, aesthetics, political philosophy, etc. To illustrate the situation, and the relations between philosophers and engineers, (Mitcham, 1998) asserts that “representatives of these areas, especially ethics and aesthetics, seem to have mounted canons on their areas of the philosophy island in order to fire away at selected domains of the engineering world”. Some philosophers as even gone so far as to claim that all main ethic and aesthetic failures of the 20th century are due to an engineering attitude that reduces nature to resources, e.g. (Heidegger, 1954)[1]. And, others assert that “technology constitutes a threat for human dignity” e.g. (Cera, 2016).

According to the classic and still standard definition that engineers give of their own profession, engineering is “the application of scientific principles to the optimal conversion of natural resources into structures, machines, products, systems and processes for the benefit of humankind” (New Encyclopedia Britannica, 1995). Then, the philosophical attack could be replaced by “Engineering is the scientific art by which a particular group of human beings destroys nature and pollutes the world in ways that are useless or harmful to human life” (Lewis C. S., 1947).

As they have become aware of such attacks engineers have become involved in the study of philosophy to be better prepared to defend themselves. However, this problem is not yet fully understood and there are no recognized engineer philosopher schools. Surprisingly, even some Liberal Arts schools (where Philosophy is also taught together with many others disciplines in a multidisciplinary context) tend to hamper the inclusion of engineering. Nevertheless, this is not a recently detected issue, and a more details will be given in the next chapter for the case of the Aerospace Engineering.

[1] pp. 13-44.

The first person to be considered an engineer philosopher is Ernst Kapp (1808-1896), a contemporary of Karl Marx. He was originally educated as a philosopher, but emigrated from Germany to the "Central Texas in the United States, where he became a pioneer and developed a view of technology as a complex extension or projection of human faculties or activities" (Mitcham, 1998). He was the first person to call this philosophical anthropology of technology by "philosophy of technology" or "philosophy of engineering". Peter Engelmeier (1855-1941) was one of the founders of the Russian professional engineering, and while talking about "philosophy of technology" he was a defensor of including knowledge about the social impact and influence of technology into the engineer education (Mitcham, 1989). The most nuclear contributor to the engineering philosophy is Friedrich Dessauer, the inventor of deep-penetration x-ray therapy. For the inventor, the first element in the creation of a technical object is the presence of human purpose. But this should not be identified either with individual or social needs. The absence of advanced technology in the prehistoric world demonstrates that individual needs alone will not produce it. Dessauer introduced the idea that a stable form of an engineering invention has a metaphysical reality prior to being brought into the physical world, transcending the Kant's system that things in themselves are always beyond the bounds a positive knowledge. This remains true for natural objects, but for Dessauer technological objects can be known as they are in themselves (Mitcham & MacKey, 1983).

Engineers actually face problems internally or professionally that they admit cannot be resolved simply with engineering methods alone such as professional ethical issues. The ethics of technology is presently characterized by a diversity of approaches (cultural, political, engineering, computer, etc.) studied by scholars with diverse backgrounds and they do not always consider themselves primarily ethicists of technology. The ABET criteria for the engineering graduate, after asserting that competence in communication "is essential for the engineering graduate", it is further affirmed that "an understanding of the ethical, social, economic, and safety considerations in engineering practice is essential for a successful engineering career" (Franssen, Lokhorst, & Ibo, 2015)[2].

With (Mitcham, 1994) a broader approach to the philosophy of technology emerged that is concerned with the technology itself and that aims to understand both the practice of designing and creating artifacts (including artificial processes and

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[2] https://plato.stanford.edu/archives/fall2015/entries/technology/.

systems) and the nature of thing so created. The inherent complexity and practical efficacy of modern technologies call forth diverse kinds of thinking – scientific and technical, of course, but also economic, psychological, political, and so forth.

1.2. Research Design and Thesis Outline

The present study is the natural continuation of the participation of the author in a project between American (Colorado School of Mines, University of Vermont, Pennsylvania State University) and the European (Université d´Orléans, Università degli Studi di Napoli "Federico II" and Universidade da Beira Interior) Universities ten years ago. The project ICEE-IT ("Interdisciplinary / International Curriculum on Energy and the Environment: Innovative Technologies") was funded under the "Program for Cooperation in Higher Education and Training"[3] of the European Union. The objectives of the project were to develop an interdisciplinary curriculum revolving around the technical, economic, social, political, and cultural aspects of energy and the environment. In the present study the perspective is quite similar, but the focus is confined to economic aspects of Aerospace Engineering.

Engineering was a recognized human activity at a certain period of the history (17th / 18th centuries) when some militaries designed, constructed, operated, and maintained fortifications and engines of war. The attempt to transfer those activities into non-military applications gave rise to the “civil engineering”, and presently each branch of engineering has a specific path. Engineering has continued to change geographically and socially, and needs to be aware of its past to enrich its present. So, in the Chapter 2 of the present work an excursion to the history of the Aeronautical Engineering in parallel with the Philosophy and Ethics is made in order to identify the relationship between them. Chapter 3 is devoted to the description of the methodology employed and selection of economic data available related to Aerospace Engineering, and its subsequent analysis. The last chapter contains the main conclusions of this study and some suggestions for future work.

[3] https://fipsedatabase.ed.gov/fipse/grantshow.cfm?grantNumber=P116J000044.

Chapter 2. Philosophy and Ethics of Aerospace Engineering

2.1. Historical Developments

According to Aristoteles, philosophy originated when human beings replaced speech about gods or the gods with speech about *phusis* (Greek) or nature (Latin). Probably Philosophical reflection on technology is about as the same age. In the Plato idea technology learns from or imitates nature, while for Aristoteles there is an ontological distinction between natural things and artifacts: the former have their principles of generation and motion inside, whereas the latter are generated only by outward causes.

The present study only approaches the field of Aeronautical Engineering that includes research, design, development, construction, testing, science and technology of aircrafts, including spacecraft. Aerospace Engineering is divided by nature in two independent but relates subjects; the aeronautical engineering while on Earth's gravitational atmosphere and astronautical engineering while on outer space (Encyclopaedia of Aerospace Engineering, 2010).

In 8th Century Before Christ, the poet Homer[4] writes that in Greek mythology a skilled craftsman[5] named Daedalus created a wide dancing ground for Ariadne (King Minos daughter) as well as the famous Labyrinth on the Greek Island Crete. Story tells that this labyrinth was intended to keep a monster half bull-half man (son of Pasiphae, wife of King Minos) away from the community. It was so well built that only Daedalus knew how to get out of it and because of that knowledge King Minos imprisoned Daedalus in a tower in Crete. It is uncertain that this labyrinth was ground level and flat as common mind thinks as it could have been a tall building with multiple floors creating that wide area for dancing but as well as the tower mentioned to keep Daedalus. Trying to escape, Daedalus created wings for himself and his son Icarus (Figure 2.1). He tied and maintained feathers together using

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[4] http://en.wikipedia.org/wiki/Homer; Retrieved 1/10/2014.

[5] "This is the workshop of Daedalus," wrote Philostratus of Lemnos in *Immagines* (1.16), "and about it are statues, some with forms blocked out, others in a quite complete state in that they are already stepping forward and give promise of walking about. Before the time of Daedalus, you know, the art of making statues had not yet conceived such a thing".

strings and wax that could suspend them on the beaten air while moving their arms. Daedalus told his son not to fly too high due to the heat of the sun so the wax wouldn't melt, and not too low so the sea water wouldn't get his feathers wet.

Homer states that they fled the island of Crete flying thru Levitha (previously known as Lebynthos), Samos and Delos. In the meantime, Icarus flew too close to the sun causing the wax on his wings to melt falling into the Aegean Sea (Figure 2.2). Icarus body was carried ashore by the sea currents and discovered by Heracles which recognized the body, buried it and named that island Ikaria in his memory (Graves, 1955).

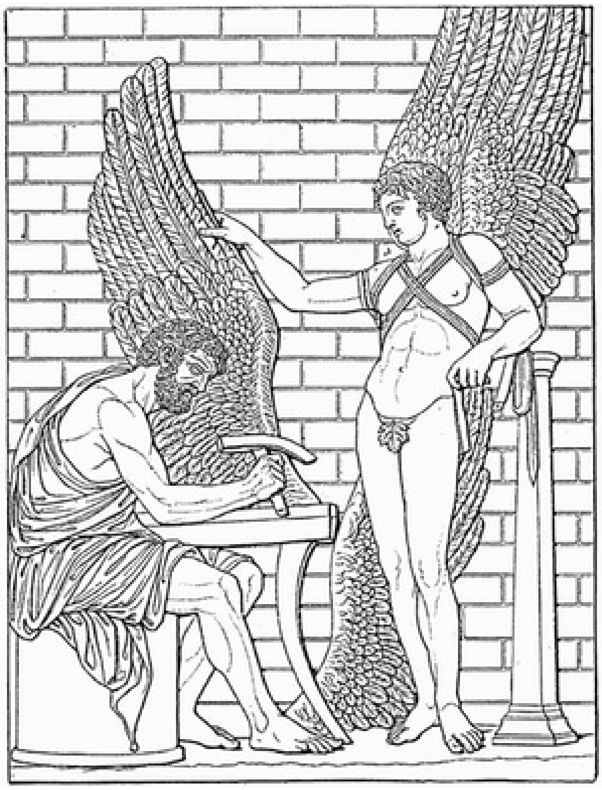

Figure 2.1 - Daedalus building Wings for his son Icarus.[6]

Figure 2.3 is intended to show the possible flight path from Daedalus and Icarus between Crete, Levitha, Samos and Delos. The island of Ikaria is also identified where the body of Icarus was found and buried.

Daedalus continued his flight towards Sicily, ruled by King Cocalus of Kamikos, where he gave his wings as an offering to god Apollo.

[6] http://www.gutenberg.org/files/9855/9855-h/images/700/127.png; Retrieved 1/10/2014.

Figure 2.2 – Painting showing Icarus falling into the Aegen Sea.[7]

Figure 2.3 – Google.com map retrieved March, 2014.

[7] Jacob Peter Gowy, La caída de Ícaro, óleo sobre lienzo, 195 x 180 cm, Madrid, Museo del Prado - https://www.museodelprado.es/imagen/alta_resolucion/P01540_01.jpg; Retrieved 1/10/2014.

Inserted in an era of amazing artistic talent, Leonardo da Vinci designed several flying machines in Italy around years 1485-1490. These "flying machines" had similarity to the Greek Daedalus and Icarus hand-made wings but with further structural built from the study of birds flying. These wing-flapping machines so called ornithopter[8] (from Greek "ornithos" bird and "pteron" wing) were based on a platform where the human rests lying down and with the use of hand-levers, foot pedals and pulleys is able to control this type of machine. Although this inventor designed these machines late 1400's, its manuscripts and notebooks were only known to public centuries after.

Figure 2.4 shows what seems to be the first drawing from this early inventor and engineer. It is visible the structural frame and hand lever movement. Several drawings from this author were discovered in different phases of development. Figure 2.5 – Wing Structure and Control System. shows a wing structural design with detail how it would work using pulleys and ropes. Figure 2.5 – Wing Structure and Control System. shows an operator using his feet to power the wing flapping machine using gears (pulleys) to multiple the strength movement to the wings. Figure 2.6 shows what seems to be his attempt to understand and study gliding flight.

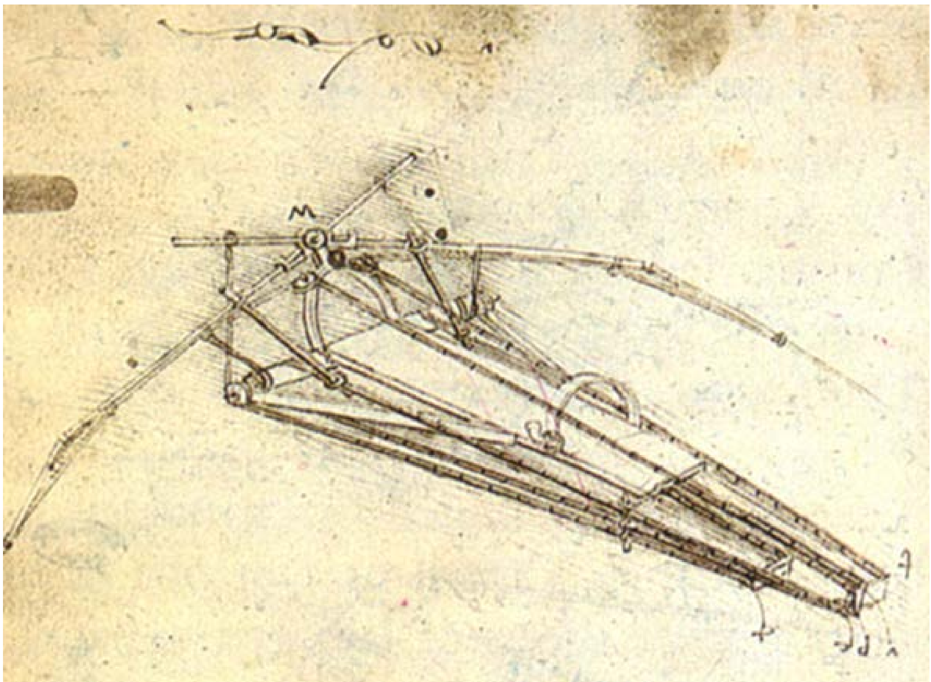

Figure 2.4 – Leonardo da Vinci Human Powered Ornithopter (1485).[9]

[8] http://en.wikipedia.org/wiki/Ornithopter; Retrieved 2/02/2014.

[9] http://wanderling.tripod.com/fly1.jpg; Retrieved 2/02/2014.

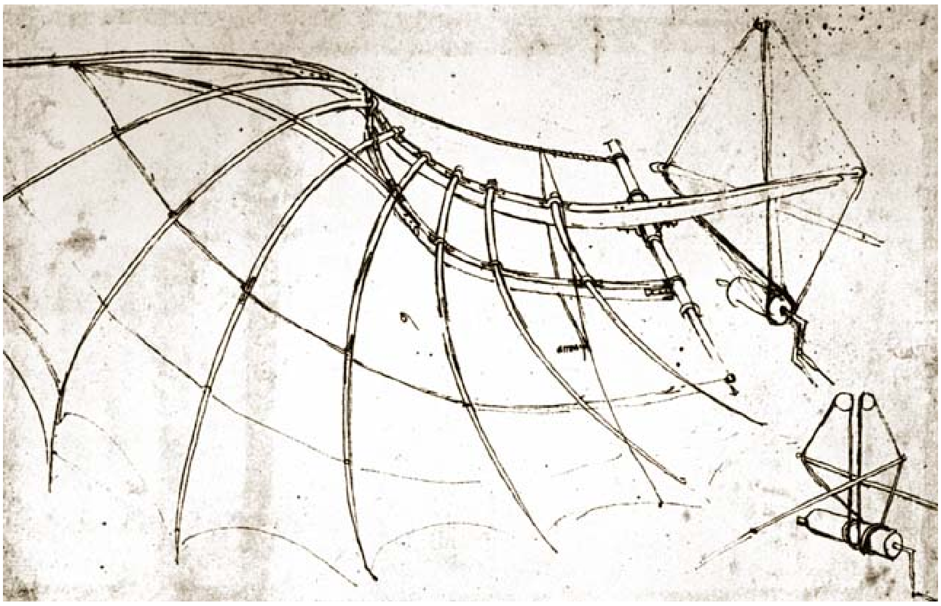

Figure 2.5 – Wing Structure and Control System.[10]

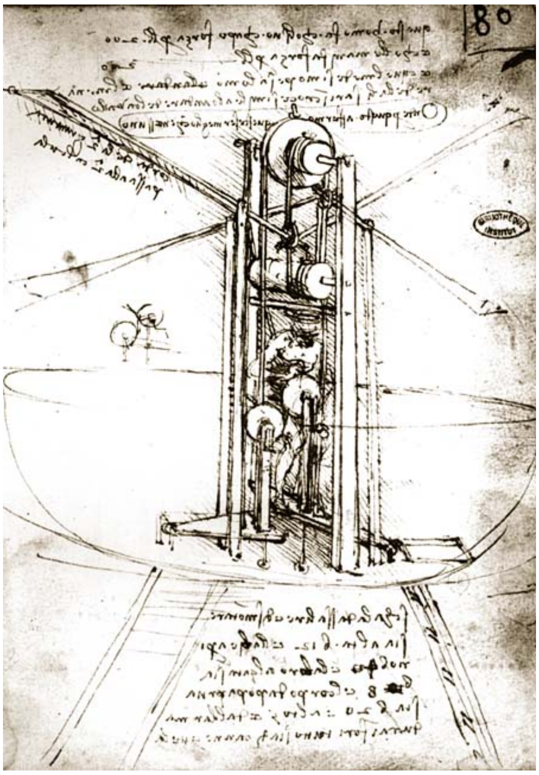

Figure 2.6 – Flying Machine. with Operator.[11]

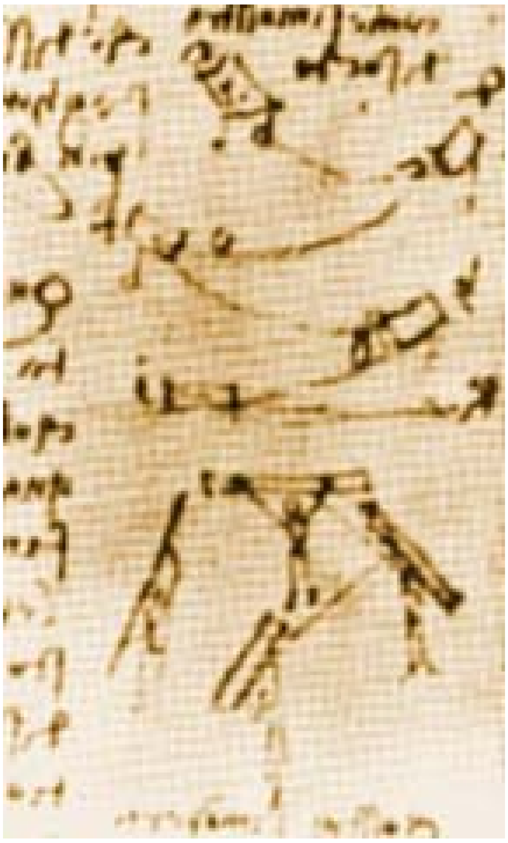

Figure 2.7 – Gliding Flight.[12]

[10] http://wanderling.tripod.com/fly3.jpg; Retrieved 2/02/2014.

[11] http://wanderling.tripod.com/fly6.jpg; Retrieved 2/02/2014.

[12] http://www.flyingmachines.org/davi.html; Retrieved 2/02/2014.

A couple of powerful metamorphoses in Leonardo's approach to flying machines and flying occurred as he went from the theory of flight to actually attempting flight. Beyond a theoretical point of view, their works had also a provision of new knowledge for the understanding of aerodynamics; he depicted turbulent flows; - and in 1507 he introduced the term - "*turbulenza*" - turbulence.

In the final of the seventeenth century the influences of Galileo (1564-1642), Descartes (1596-1650), Newton (1596-1642), and their followers induced a vision of the world in an Aristoteles's way.

The idea of flying ships initiated in the 17th and 18thcentury where in 1670 Father Francesco Lana de Terzi[13], identified as the "Father of Aeronautics", draw a ship being levitated by copper vacuum-spheres (see Figure below).

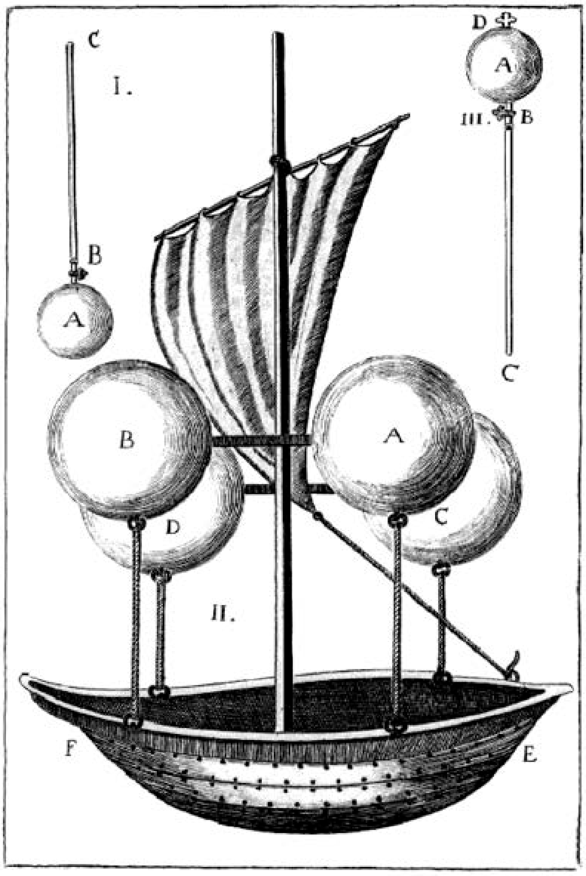

Figure 2.8 – Father Francesco Flying Boat.[14]

[13] http://www.faculty.fairfield.edu/jmac/sj/scientists/lana.htm; Retrieved 2/07/2014.

[14] http://en.wikipedia.org/wiki/Francesco_Lana_de_Terzi; Retrieved 2/07/2014.

In spite of all of these attempts for raising funds and drawings, only in June of the year 1783 the French Montgolfier Brothers created the hot air balloon[15]. Suddenly others joined this idea modifying initial design, development and operation of these balloons. This first balloon was created in linen sackcloth with rag paper lining and connected using approximately 1800 buttons. This first unmanned flight was a success although the rain and the sharp eyes of the official observers reaching almost 3000 feet altitude. This balloon drifted 1.5 miles from its departure location due to air currents and burned when it reached the ground again. Although it burned, their project was a tremendous success and the Montgolfier Brothers began to make another balloon. This next balloon was intended to demonstrate their invention before the Academy of Science in Paris with the intent of raising funds for this new field of engineering.

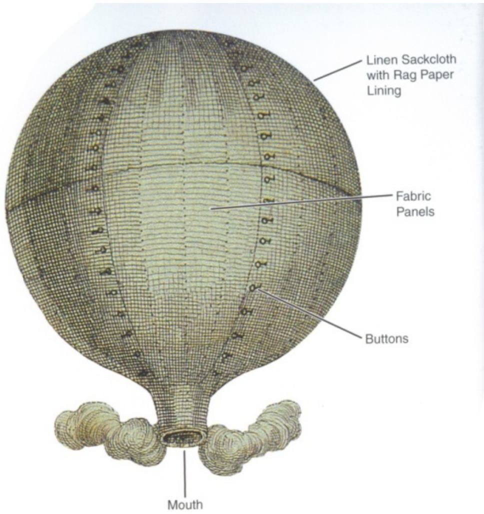

Figure 2.9 – Montgolfier's First Balloon. (Jeppesen, 2006)

When they arrived to Paris, they discovered that the Academy already gave a grant to a physicist named Jacques Alexander César Charles (Gay-Lussac, 1802). Mr. Charles decided to use hydrogen to lift the balloon and with the help of the Robert Brothers[16], they dissolved rubber in turpentine allowing the silk taffeta fabric (previously identifies as linen sackcloth with rag paper lining) and the union between these fabric panels. In August 27th of 1783, Charles and his workers released this

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[15] http://en.wikipedia.org/wiki/Montgolfier_brothers#cite_note-Gillispie-2; Retrieved 2/07/2014.

[16] Federation Aeronautique Internationale, Ballooning Commission, Hall of Fame, Robert Brothers.

balloon where in less than two minutes rose around 1500 feet and disappeared in the clouds. In less than an hour, this balloon hit the ground 13 miles north of Paris scaring the peasants where they attacked the crashed balloon with pitchforks[17] (see Figure 2.10).

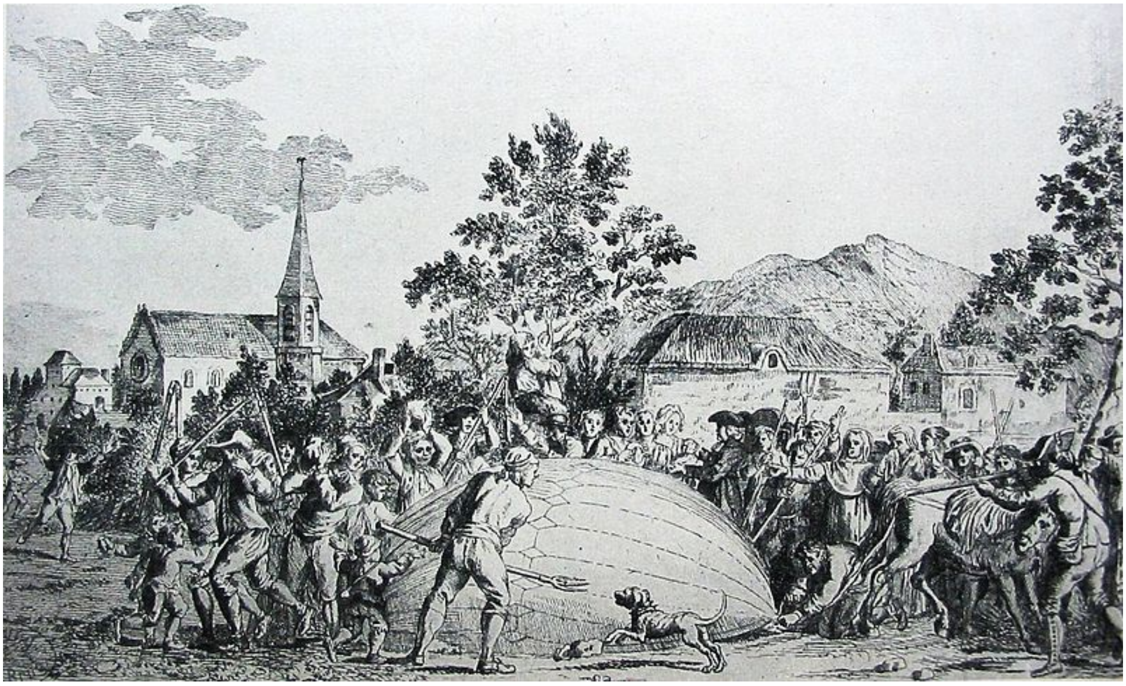

Figure 2.10 – Charles Balloon is attacked by terrified villagers.[18]

The Montgolfier Brothers continued their work and were able to get financing from the Academy of Science and the Ministry of Finance. A second balloon was created and it passed a test flight while held using ropes however rain present next day forced them to cancel the balloon ascension.

Within a week, the Montgolfier brothers developed another balloon but this time made of taffeta cloth and wallpaper covered reinforced with varnish on its exterior and paper lined inside. With 41 feet diameter and a cage to carry animals, this third balloon was ready to take flight. On September 19th, 1783 King Louis XVI accompanied by Maria Antoinette and the French Court at Versailles watched the eight-minute flight that was carrying a sheep, a duck and a rooster (Figure 2.10). The balloon raised 1500feet and landed safely 2 miles after – this was another tremendous success to the Montgolfier Brothers.

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[17] Today in Science, The Montgolfier and Charles Balloons, from 1911 Encyclopedia Britannica.

[18] http://en.wikipedia.org/wiki/File:WasserstoffballonProfCharles.jpg; Retrieved 2/20/2014.

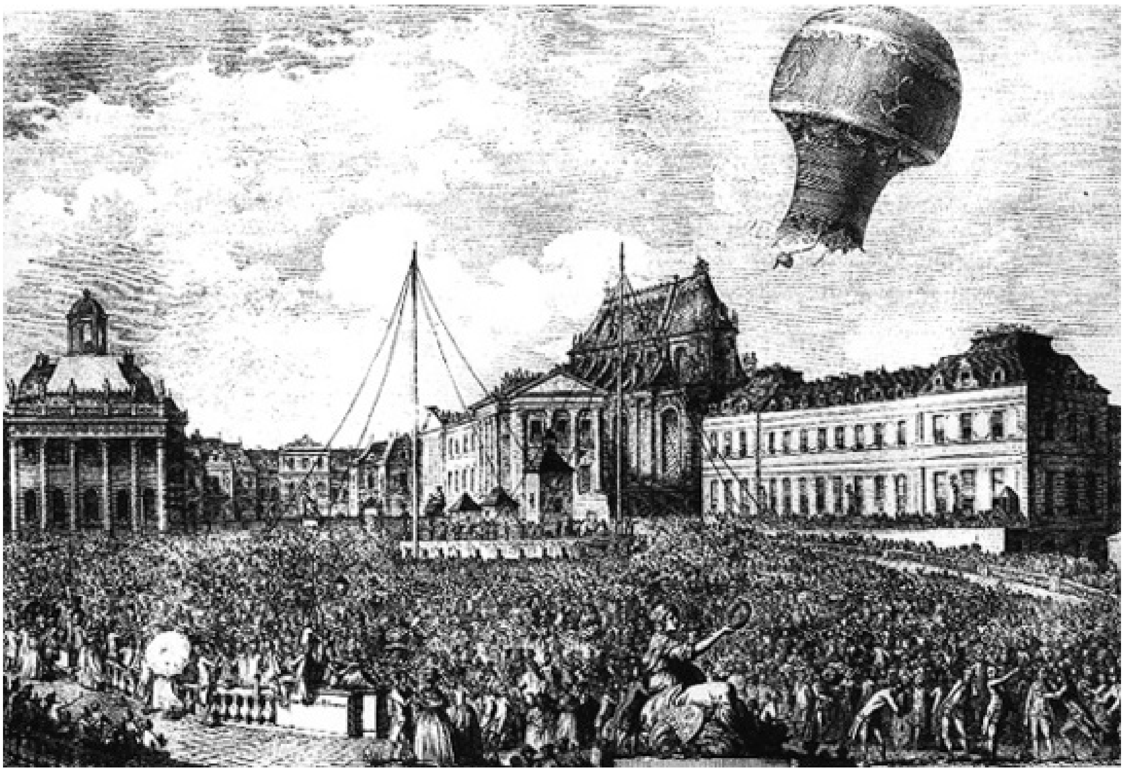


Figure 2.11 – Balloon with Cage carrying Sheep, Duck and a Rooster.[19]

In spite of his father request, Étienne Montgolfier was the first un-official human in history to be airborne while tethered to the ground. Because of a promise to his dad, this fact was never published but written in a letter to his wife and made public years after. Using a Montgolfier balloon Pilatre de Rozier and the Marquis François Laurent (le Vieux d'Arlandes) in November 21st of 1783, made the first free flight by humans (Figure 2.11). On October 15th 1783, the Montgolfier Brothers launched a tethered balloon with Jean-François Pilâtre de Rozier, a chemistry and physics teacher, aboard. He stayed aloft for almost four minutes.

After this amazing achievement the Robert Brothers continue on their hydrogen balloon development and with these two types of balloons, hot air and hydrogen, the world of aviation was initiated. On June, 26th 1794 Napoleon's assigned a balloon to the Republic army for terrain surveillance. Shortly after ballooning became super popular spreading across the world for pleasure and military actions (Figure 2.13).

[19] National Air and Space Museum, Smithsonian Institution, Washigton, United States of America.

Figure 2.12 - Description of the Montgolfier Balloon.[20]

Figure 2.13 - Balloon used in the battle of Fleurus.[21]

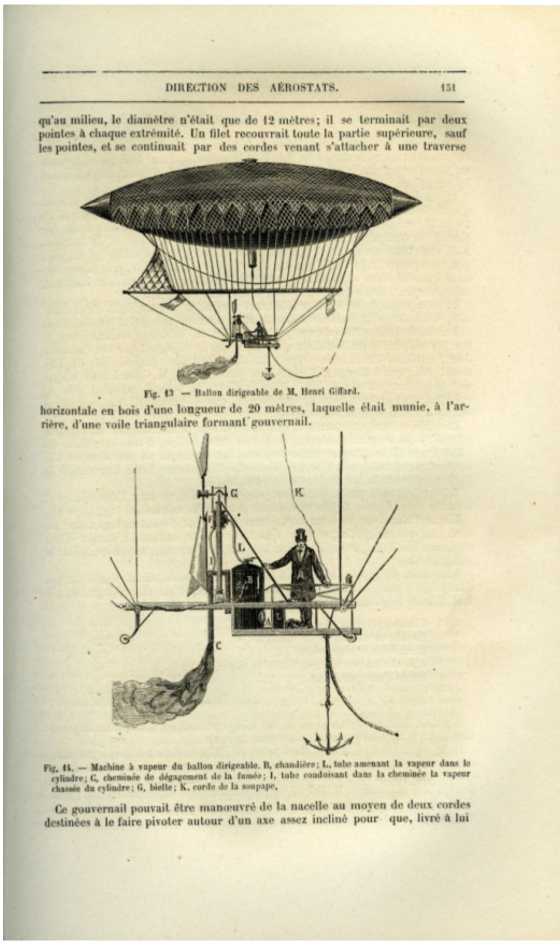
[20] http://en.wikipedia.org/wiki/File:1783_balloonj.jpg; Retrieved 2/20/2014.

[21] http://www.sciencemuseum.org.uk/objects/penn-gaskell_collection/1946-125.aspx; Retrieved 2/20/2014.

These balloonists kept improving until the so well-known dirigibles. These dirigibles are balloons with the ability to be steerable. These became semi-rigid where they are able to levitate due to internal gas pressure (lighter than air) balancing and overcoming its mass and rising.

In November 30th of 1784, John Jeffries and Jean Pierre Blanchard tried to maneuver a hydrogen balloon using wings and oars (Figure 2.14) followed by Henri Giffard in 1852 using a 3 Horsepower (HP) steam engine to rotate a propeller able to fly for 6 miles per house (Figure 2.15).

Figure 2.14 –John Jeffries Balloon with Wings and Oars.[22]



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qu'au milieu, le diamètre n'était que de 12 mètres; il se terminait par deux pointes à chaque extrémité. Un filet recouvrait toute la partie supérieure, sauf les pointes, et se continuait par des cordes venant s'attacher à une traverse

Fig. 13 — Ballon dirigeable de M. Henri Giffard.

horizontale en bois d'une longueur de 20 mètres, laquelle était munie, à l'arrière, d'une voile triangulaire formant gouvernail.

Fig. 14. — Machine à vapeur du ballon dirigeable. B, chaudière; L, tube amenant la vapeur dans le cylindre; C, cheminée de dégagement de la fumée; I, tube conduisant dans la cheminée la vapeur chassée du cylindre; G, bielle; K, corde de la soupape.

Ce gouvernail pouvait être manœuvré de la nacelle au moyen de deux cordes destinées à le faire pivoter autour d'un axe assez incliné pour que, livré à lui

Figure 2.15 – Henri Giffard Steam Engine Balloon.[23]

[22] http://www.loc.gov/exhibits/treasures/images/wb0109s.jpg; Retrieved 3/11/2014.

[23] http://biblioeuitiupm.wordpress.com/2008/10/31/la-euiti-en-la-viii-semana-de-la-ciencia/ballon-dirigeable-de-m-henri-giffard/; Retrieved 3/11/2014.

From 1852 to 1914 dirigible balloons undergone Zeppelin's and went from semi-rigid to aluminum sheet (fully-rigid frames). In the year 1914, also known as the start of World War I (WW I), the latest and unique Zepellin LZ4 was used for military purpose.

From Charles Gibbs-Smith, British historian, "the kite is in reality a primitive airplane – a craft supported in the air by the action of wind upon an inclined surface – and the windmill is a propeller." There are records around the 5th Century B.C., that the Chinese invented the kite and that the windmill originated from Rome in the 12th Century. Only later in 1784 the windmill was given the proper aeronautical importance and that same year Professor Launoy and Bienvenu created a simple helicopter with rotors on both ends of a pole (Figure 2.16). Monsier Vallet created and tested a propeller on a river boat and a year later, in 1785, tested it on balloons. This propeller was the first attempt to propel balloons. The term propeller has Latin origin "propeller" meaning drive forward, translated as an airscrew in British and a revolving fan (moulinet) in French.

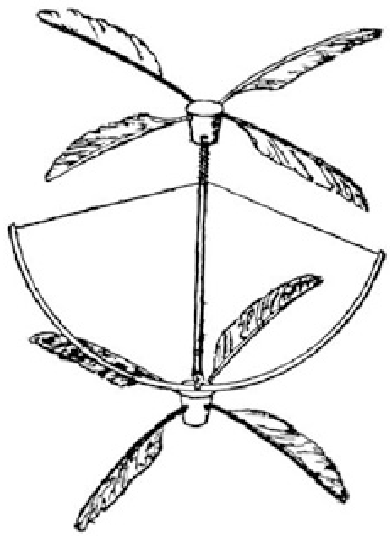

Figure 2.16 – Drawing of Launoys and Bienvenue's model Helicopter.[24]

The airplane as we know it nowadays started with Sir George Cayley[25] who identified physics laws as lift, drag and thrust as well as the mechanical problem of flight – "to make a surface support a given weight by the application of power to the resistance of the air." This was quite an unnatural conclusion since there is no example of such idea in the nature. On his three published articles ("On Aerial Navigation", 1809,

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[24] Apostolo "The Illustrated Encyclopedia of Helicopters", 1984.

[25] http://en.wikipedia.org/wiki/George_Cayley; Retrieved 4/1/2014.

1810, 1810) Cayley was the first to identify the four aerodynamic forces of flight weight, lift, drag, and thrust and their relationship. Sir George studied air resistance in ballistics and windmills which led him to create the first model glider (Figure 2.17 – 1804 Glider). This glider included same paper used in kites as the wings a pole that served as a body or fuselage.

To overcome the rotation in the vertical or yaw axis, Sir George developed an empennage identifying the rudder and elevator. This glider was also equipped with a moveable weight to adjust for proper CG [Center of Gravity]. Experimenting this glider, Sir George had assistants run to the point that they would be lifted several yards at a time. In 1809 Sir George built a 200 sq. ft. full-size glider and it flew without passengers successfully but he recognized the need for power – he then spends several years trying to create a perfect solution without any good results. Getting back into building gliders, he created a small glider able to carry a ten-year-old boy while being towed by a rope. In the same year, 1853, he created a bigger glider able to carry a full-grown man. This man flew this glider freely across the valley and crashed it upon landing (Figure 2.17 – 1852 Glider).

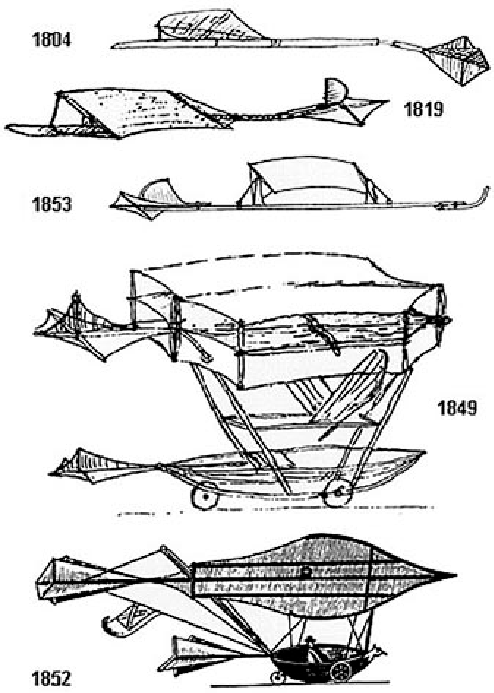

Figure 2.17 – Sir George Cayley Gliders from 1804 to 1852.[26]

[26] http://www.ctie.monash.edu.au/hargrave/cayley.html; Retrieved 4/1/2014.

Others followed Sir George's passion for aeronautics. William Samuel Henson and John Stringfellow created a monoplane (one wing airplane) where the wing had a new curved feature later defined as camber and a steam engine turning a six-blade propeller (Figure 2.18). First flight test wasn't successful and Henson abandoned the project – on the other hand Stringfellow continue his adventures and in 1847 released a ten-foot steam-powered glider that flew and created attention again (Figure 2.19).

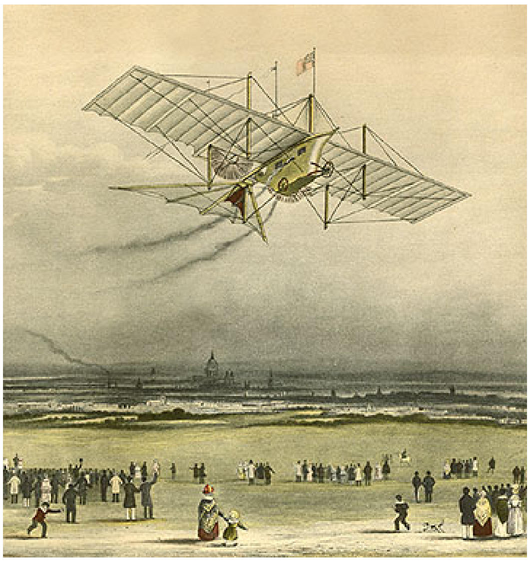

Figure 2.18 – Cropped print of the Aerial Steam Carriage "ARIEL" in 1843.[27]

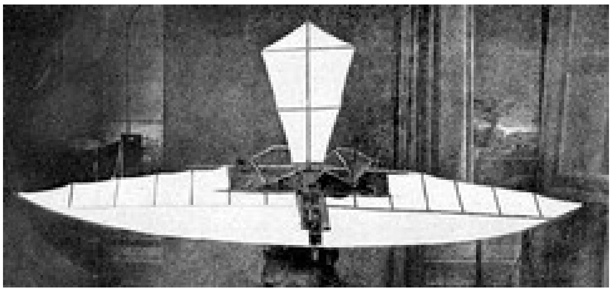

Figure 2.19 –Stringfellow's 10 Foot Wingspan Monoplane (1847).[28]

In 1874, Félix du Temple, a French Naval Officer, created a tractor airplane (propeller pulling the airplane forward) that took off without man's help – this was the first powered takeoff.

A couple of decade's later, German engineer Otto Lilienthal logged almost 2000 flights covering between 300 to 750feet using gliders. He used fixed-wing airplanes shaped like bat wings where the pilots body mass would control the flight pattern. Otto also created foldable wings (for transport), rear elevator, leading-edge flaps

[27] http://www.flyingmachines.org/hens.html; Retrieved 4/1/2014.

[28] http://www.wright-brothers.org/History_Wing/History_of_the_Airplane/Doers_and_Dreamers/Doers_and_Dreamers_S.htm; Retrieved 4/15/2014.

and ornithopter wingtips. Otto died in 1896 after a crash but his ideas prevailed and were acknowledged.[29]

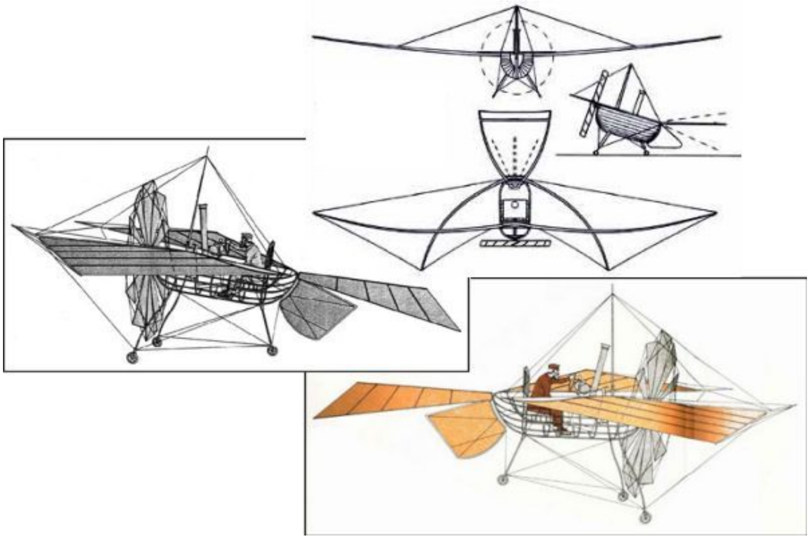

Figure 2.20 – Drawings of Félix du Temple's 1874 Tractor monoplane.[30]

Figure 2.21 – Otto in mid-flight 1895.[31]

[29] http://www.lilienthal-museum.de/olma/ewright.htm; Retrieved 4/15/2014.

[30] http://www.aerospaceweb.org/question/history/q0172.shtml; Retrieved 4/15/2014.

[31] United States Library of Congress's Prints and Photographs division under the digital ID ppmsca.02546;http://en.wikipedia.org/wiki/File:Otto_Lilienthal_gliding_experiment_ppmsca.02546.jpg; Retrieved 4/15/2014.

French Civil Engineer Octave Chanute built in 1896 in the surroundings of Chicago (USA), several man-carrying gliders using Cayley's camber shaped wings and tail sections and Otto's flight experience. He used the Pratt truss technology from bridge construction and applied it to brace the wings. A fellow young man with passion in aviation helped Chanute and successfully flew over Indiana Dunes on the shore of Lake Michigan on a kite based on work of German Otto Lilienthal (Figure 2.22). Later on the Wright Brothers read Chanute and Lilienthal's experiments and after a personal visit he encouraged the Wright Brothers to continue their quest in powered flights.

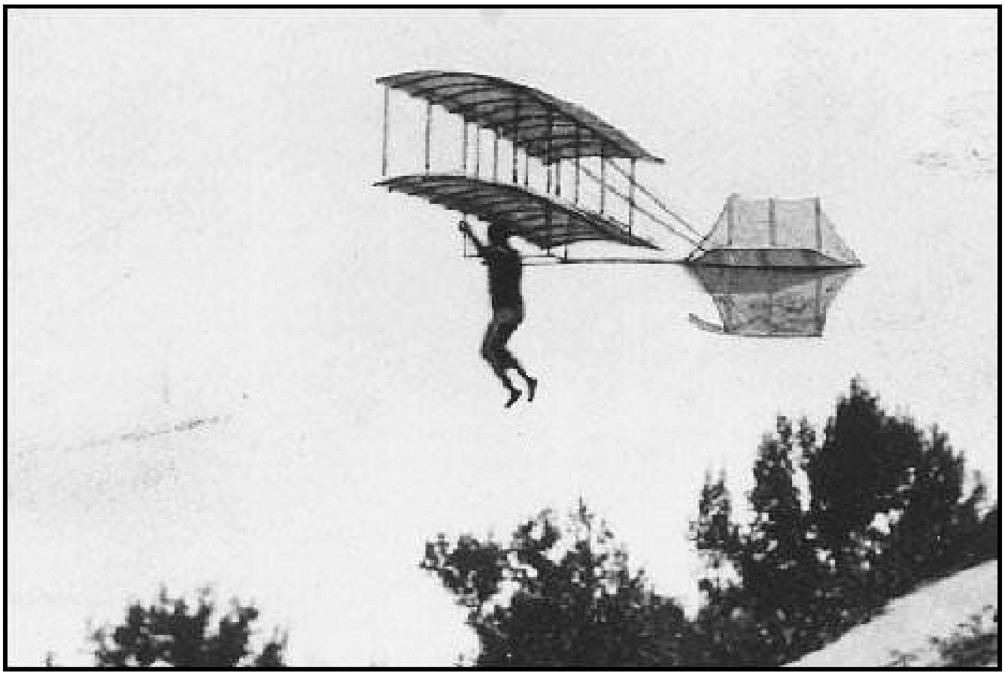

Figure 2.22 – Chanute-Herring Glider in 1896.[32]

As mentioned above, Orville and Wilbur Wright, also known as the Wright Brothers, were not the first ones to develop and experiment aircrafts. They were however the first ones to successfully add controls to the aircraft allowing a fixed-wing powered flight possible.[33] With their printing presses, bicycles manufacturers, motor and other mechanical components experience they realized that they needed to control equilibrium while in flight developing the three-axis control.[34] After reviewing prior

[32] http://spicerweb.org/Chanute/ImagesCont/fly_nice.jpg; Retrieved 4/24/2014.

[33] http://en.wikipedia.org/wiki/Wright_brothers.

[34] "Inventing a Flying Machine - The Breakthrough Concept", The Wright Brothers and the Invention of the Aerial Age, Smithsonian Institution. Retrieved 4/25/2014.

flight attempts and their reported experience from others, as mentioned above, Wilbur noted thru the study of birds that the angle at the end of the wings made them roll left or tight (Tobin, 2004). They thought that if they would be able to control by banking or leaning to one side, similar to the body motion with Chanute's glider they would be able to control side wind flows allowing continuous flight. This idea brought them to wing-warping effect using a long inner-tube (Tobin, 2004).

Figure 2.23 represents Wright Brothers 1899 kite where it shows how they achieved the wing warping using strings while in flight for control. It is visible their thought process how to control the wing ends using their hands while linked thru strings.

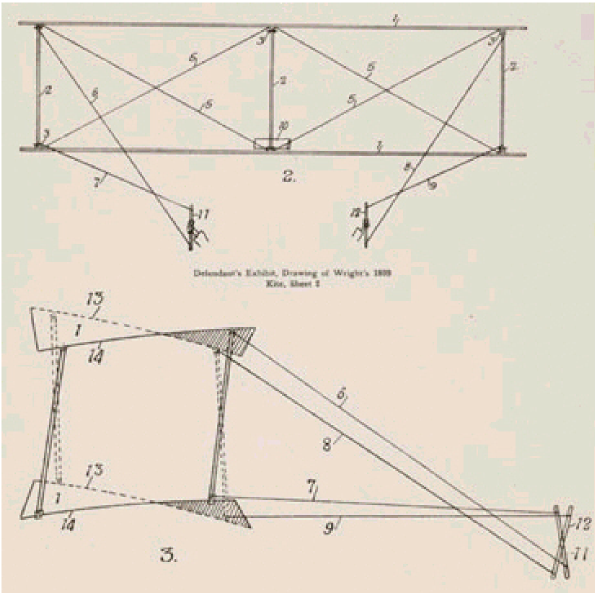

Figure 2.23 – Wright Brothers 1899 Kite.[35]

That same year, Wilbur tested the warping wing by creating a biplane kite with a 5 feet wingspan where he tried various parameters and warping amounts. After reviewing Chanute-Herring's design, along with the information that Lilienthal published plus Sir George Cayley camber wing principle, the Wright Brothers developed a glider that contained most of the aeronautical principles from those mentioned above plus the fact of a forward horizontal elevator to help them in case of a nosedive.[36] Wilbur Wright flew in Kitty Hawk this glider while several men held

[35] Part of "The Dream of Flight" online exhibit in the American Treasures section at the U.S. Library of Congress; Retrieved 4/25/2014.

[36] Wright, Wilbur."Some Aeronautical Experiments" Western Society of Engineers, September 18, 1901. Retrieved: 4/29/2014.

tether ropes to control this aircraft (Crouch, 1989)[37]. Figure 2.24 shows the forward horizontal elevator, the cambered wings principle as well as the “Pratt truss” bridge design.

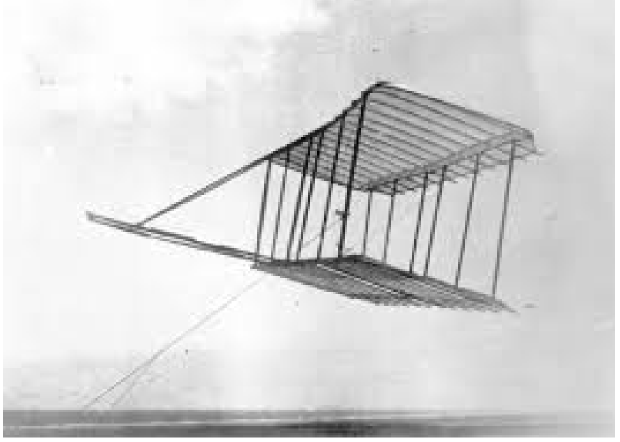

Figure 2.24 – 1900 Glider being used as a Kite.[38]

With the challenge of the amount of lift necessary versus the human weight, the Wright brother developed another glider with a large wing area but faces disappointment as the lift desires was only one-third of the calculated and the glider wasn’t responding to wing wrapping inputs.[39] Suspicious that previous published studies were incorrect, the need to save overall costs in test flights and aircraft; they built a six-foot wind tunnel (Figure 2.25) and performed various tests on reduced scale wings.

With these wind tunnel tests, the Wright brothers discovered among other crucial parameters that longer and narrower wings would increase the lift-to-weight ratio. With this principle, they were able to counterbalance lift for a steady flight while overcoming issues like drag and weight amounts.[40] In October 1902 they resume their actual testing and applied the knowledge gathered from the wind-tunnel. First flight in October 10th (Figure 2.26) was done using a steerable rear rudder, replacing the double fixed rudder and a couple of weeks later in October 24th (Figure 2.27)

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[37] pp. 188-189.

[38] http://www.wright-brothers.org/Information_Desk/Just_the_Facts/Kites_&_Gliders/Kites_&_Glider_images/1900-Wright-Glider-kited-at-Kitty-Hawk.jpg .

[39] “1901 Wright Glider”, Wright Brothers Aeroplane Company; Retrieved 04/29/2014.

[40] “Kitty Hawk in a Box” Wright Brothers Aeroplane Company; Retrieved April 30, 2014.

tested using a moveable rudder with the intent to align the aircraft while banking and leveling after turns.

Figure 2.25 – Wright Brother's Wind Tunnel Replica.[41]

Figure 2.26 – October 10th, 1902 Flight.[42]

Due to the success of controlled flight, they moved on to a powered flight for continuous flight. They believed that a powerful engine was not the solution for proper flight control and with the help of Charlie Taylor, their mechanic at the bicycle shop they developed their own custom engine in 6 weeks (Crouch, 1989)[43].

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[41] Dodson, M.G. "An Historical and Applied Aerodynamic Study of the Wright Brothers' Wind Tunnel Test Program and Application to Successful Manned Flight."US Naval Academy, Technical Report, Volume USNA-334, 2005; Retrieved: 04/29/2014.

[42] Library of Congress,ppprs 00604. http://hdl.loc.gov/loc.pnp/ppprs.00604; Retrieved April 30, 2014.

[43] pp.245.

The so well-known Wright Flyer I was made out of spruce wood, home-design and carved propellers and a cast aluminum engine block made at the bicycle shop.[44] In December 17th, 1903 they made successful flights of 120 feet length in 12 seconds (Figure 2.28) and later on one of 200 feet.

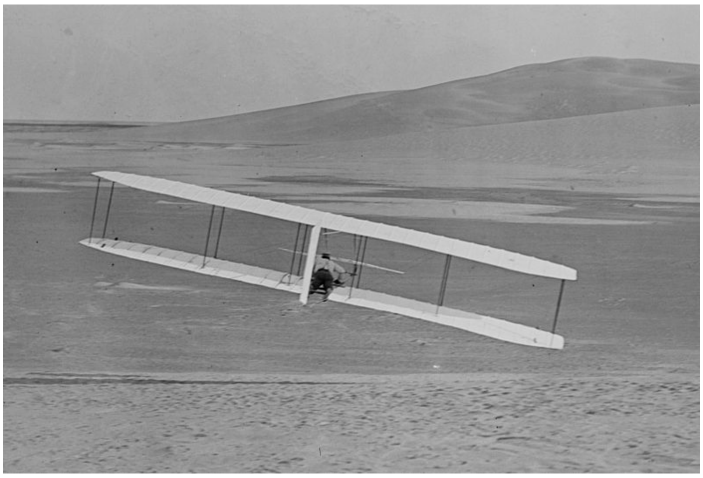

Figure 2.27 – October 24th, 1902 Flight.[45]

Figure 2.28 – Wright Flyer I 1st Flight December 17th, 1903.[46]

[44] "Milestones of Flight - 1903 Wright Flyer"-Smithsonian National Air and Space Museum.

[45] Library of Congress,pppprs 00598, http://hdl.loc.gov/loc.pnp/ppprs.00598; Retrieved April 30, 2014.

[46] Library of Congress,pppprs 00626. http://hdl.loc.gov/loc.pnp/ppprs.00626; Retrieved April 30, 2014.

Flight tests continued as well as aircraft improvements creating the Wright Flyer II and III in 1904 and 1905 respectfully. They continued to learn with their experiences and increasing flight lengths and speeds (Figure 2.29 and Figure 2.30).

Figure 2.29 – November 9th, 1904.[47]

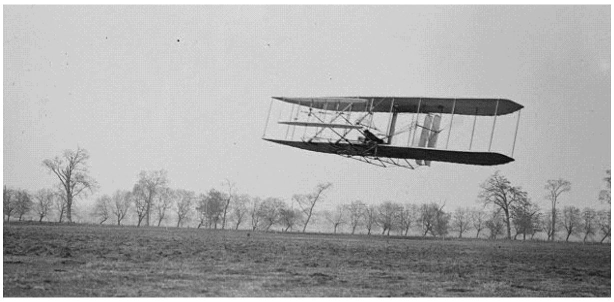

Figure 2.30 – October 4th, 1905 Flight.[48]

In the next couple of years, the Wright Brothers focused on trying to sell their flying machines to the US and European government with no success. Trying to overcome this obstacle, they traveled to France where they met a lieutenant from the US Army Aeronautical Division which persuaded his superiors to give the Wright Brothers a chance to show what they accomplished. In 1907 Wilbur sailed towards France and Orville went to Washington, US where they would demonstrate that they could fly with one more human person closing on the agreement of manufacturing aircrafts for the US Army and a French company. With successful flights they were able to build aircrafts under these two contracts and this was the beginning of the Wright Company (Crouch, 1989).[49] Mid 1910 the Wright brothers change the aircraft design moving the elevator to the back to help control the climb and descent at higher speeds. Several fatal Army accidents caused the cancelation for that contract under the statement that the aircraft was “dynamically unsuited for flying”.[50]

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[47] http://en.wikipedia.org/wiki/File:WrightFlyer1904Circling.jpg; Retrieved April 30, 2014.

[48] Library of Congress, ppprs 00616 http://hdl.loc.gov/loc.pnp/ppprs.00616; Retrieved April 30, 2014.

[49] pp. 410.

[50] The Signal Corps Takes to the Air.”. Retrieved 04/30/2014.

In the meantime, a series of patents issues and lawsuits took place between the Wright Company and Glenn Curtiss (Curtiss Aeroplane Company) which refused to pay license fees to the Wrights. Court judges gave the Wright Company the reason and Curtiss had to pay however in 1917 with World War I, the US Government demanded a cross-licensing organization called Manufacturers Aircraft Association where each member had to pay fees for the use of aviation patents, including its original developers.[51,52] In 1929 Curtiss-Wright Company was created and they are still in business making high-tech components for the aerospace industry.[53]

Another important mark in history was the forgotten Gonzales Brothers (Figure 2.31). They did not invent the airplane but they continued the Wright Brothers legacy and similar business plan. Will and Arthur Gonzales were two young twin boys with third grade education, a passion for flying and no funds to accomplish their goal. They started with designing and building larger size kites and soon gliders carrying people.

Figure 2.31 - Practice Flight in Woodland, CA.[54]

In 1908 with the hope to move forward to powered flight they started the design of Gonzales #1 biplane that would accommodate an engine allowing this aircraft to take off from the ground. The engine selected was an in-line 4-cylinder Kemp Engine (Figure 2.32) and a Paragon propeller (Figure 2.33) all for $450 – expensive at the time. While in San Francisco, California they couldn't perform flying tests and

[51] Wicks, Frank. "Trial by Flyer" at the Wayback Machine (archived June 29, 2011) *Mechanical Engineering 100 Years of Flight;* Retrieved from Web Archive 04/30/2014.

[52] Glenn Curtiss and the Wright Patent Battles. *Centennialofflight,* 2003. Retrieved 04/30/2014.

[53] http://www.curtisswright.com.

[54] https://doolittlecenter.org/html/gonzales.html; Retrieved 05/01/2014.

therefore disassembled the aircraft and moved to Woodland in Northern California where they had long flat areas for temporary flying tests.

Figure 2.32 – Kemp Engine.[55]

Figure 2.33 – Bob Gonzales and Paragon Propeller.[56]

As mentioned before, due to patent infringement issues, the Wright Brothers visited the Gonzales Brothers shop and their biplane. They found no patent infringements and even lend them some money. In August 8th, 1918 they relocated once more to Los Angeles, California where they modified their initial design with tail feathers and ailerons. They created and established the Gonzales Bros. Aeroplane Manufacturing and Supply Company (Figure 2.34) but there's no history of any other airplanes or designs.

Figure 2.34 – Gonzales Company Trademark.[55]

Figure 2.35 – Gonzales #1 Biplane.[56]

In 1972 the Gonzales#1 biplane passed on as an inheritance within the family where it was repaired and back into working conditions. After various air shows and a 12

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[55] https://doolittlecenter.org/Publication2GonzAero.pdf; Retrieved 05/01/2014.

[56] https://doolittlecenter.org/html/gonzales.html; Retrieved 05/01/2014.

year display at the Hiller Museum in San Carlos, California (Figure 2.36) the original Gonzales biplane now rest for educational purposes inside of a family hangar.[54,55]

Figure 2.36 – Gonzales #1 in Hiller Museum.[56]

From the Wright Brothers published developments to World War I, the aviation industry boomed with different airplane constructions, with first flights and their records. It became an industry from the early inventor to their business partners. As stated above, upon the return of the Wright Brothers to flying, they discovered that Europe was far advanced due to their government support. By 1910, France was the world leader in aviation followed by Britain, Germany, Russia and Italy. The two remarkable US inventors, Wright Brothers and Glenn Curtiss, were busy fighting their patents and lawsuits on each other while Europe continues with their airplane and technology developments.

Patent infringements were filed by the Wright Brothers not only in the US but in Germany, France and Great Britain. The German claim lost its ground due to the fact that Octave Chanute gave a conference in Berlin University describing wing warping before the Wright's patent application was issued. The French claim, against six different manufacturers, was accepted and ruled-out in favor of the Wright Brothers. However, the plaintiffs defended their point with extensions and countersuits until the expiration of those patents in 1917. Great Britain government was the only country that gave patent rights to the Wright Brothers and that actually paid them for those infringements.

In 1913, the Wright Brothers filed a patent for automatic stability using a pendulum to control yaw, roll and pitch changes. This development was not state-of-the-art, as Lawrence Sperry had developed the gyroscopic stabilizer in 1914 (see Figure 2.37). At the same time, while Wrights airplanes had three levers to warp the wings, to set the rudder and to adjust the elevator, the Curtiss airplanes possessed a control wheel that allowed the pilot to pull or push to control the elevator, turning to control the rudder and a shoulder yoke to control the ailerons. The airplane/aircraft industry was growing rapidly in both military and civil use.

With the start of aviation industry, the need for engines, flight schools and airports was inevitable. Engines from two to sixteen cylinders in vertical, horizontal, radial, V, opposed or tangent format were created mainly by France, Germany and the US. Since early 1909, Louis Bleriot started mass production of the Bleriot XI (Figure 2.38) airplane and by 1911 he logged the 500th Bleriot out of his factory. For all of these airplanes he discovered the need to teach their owners or future pilots how to fly. Airplane owners were taught to fly for free, while other students had to pay a fee plus damaged parts.

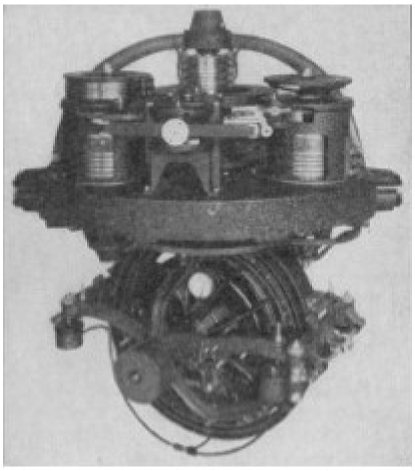

Figure 2.37 – Lawrence Sperry gyroscope.[57]

[57] http://www.wright-brothers.org/History_Wing/History_of_the_Airplane/Decade_After/Girding_for_Battle/Girding_for_Battle_images/Lawrence-Sperry-and-gyroscopic-stabilizer.jpg; Retrieved 05/05/2014.

Figure 2.38 – Bleriot XI in Flight.[58]

The construction of airports or a specific area dedicated for taking-off and landing was of extreme importance for the safety of the airplane, structures surrounding it and their pilots. Open land pastures with easy access to public, good year-round weather conditions and the ability to build hangars, living quarters made the perfect landing strips. Some of these locations were also close to water beds allowing floats (pontoons) take-offs and landings. The military used their fields for training and maneuvers while manufacturers used their designated fields for flight tests and demonstrations.

With the need to guide pilots while flying from one location to the other, the need for ground references and defined directions began. These references were initially on the ground, painted on top of building roofs or by captive balloons. Due to the fact that pilots used ground references with the help of a compass to guide them thru flight, the French and German military published in 1911 the first aeronautical maps individually. In that same year, the First International Congress of Aerial Law met in Paris and from these meetings a first set of laws became official.

These initial laws were simple:

- Air traffic is free but subjected to that nations regulations (if applicable);

[58] Library of Congress, ggbain 04066. http://hdl.loc.gov/loc.pnp/ggbain.04066; Retrieved 05/05/2014.

- Every aircraft needs to be registered and the residence if its owner determines its country;
- Every aircraft displays a mark of its nationality;
- Landings could be done in an open field but not within cities or military infrastructures;
- It is strictly forbidden to drop objects that could hurt people or property, and;
- Wrecked or abandoned aircrafts could be claimed by its owner one year of that discovery upon payment of search, salvage and preservation costs.

These rules got iterated several times getting more and more complex. These rules history and understanding will be studied and developed in the Regulations chapter.

World War I was the first major conflict to feature a wide variety of military aircraft as air power superiority; countries were assembled in two opposing alliances:

- Allied Powers: France, United Kingdom, Russia, Belgium, Japan, Portugal (1916-1918), United States (1917-1918), Greece (1917-1918) Italy and others. (Italy ended its alliance with the Central Powers arguing that Germany and Austria-Hungary started the war and that the alliance was only defensive in nature; it entered the war on the side of the Allied powers in 1915);
- Central Powers: Germany, Austria-Hungary, Ottoman Empire, Bulgaria (1915-1918).

Portugal remained neutral at the start of the conflict in 1914; even though Portuguese and German governments stayed officially neutral for over 1 ½ year after the outbreak of WWI, there were many hostile engagements between both countries. Portugal wanted to comply with British requests for aid and protect its colonies in Africa, thus clashes occurred with German troops in 1914 and 1915 (South of Angola – which bordered German South-West Africa). Germany/Portugal tensions also arose as a result of German U-boat warfare, which sought to blockade the U. K., at the time the most important market for Portuguese products. Ultimately, tensions resulted in declarations of war, firstly by Germany against Portugal in March 1916.

At Mozambique along operations against German Eastern Africa in 1917, the Portuguese forces included a small squadron of a modified Farman MF.11, one of the first employments of military aircraft in Africa. During WWI, several Portuguese airmen flew in British and French squadrons; pilot Óscar Monteiro Torres became the first Portuguese airmen to be killed in an air combat.

German troops entered Belgium heading to France in mid-1914 using trains, trucks, cars, horses and by foot. Lighter-than-air equipment was only used for reconnaissance. WWI was mostly fought inside trenches where soldiers were protected by dirt. In the beginning German Army had six rigid-frame Zeppelins and the German Navy had two. The German Army retired their airships a couple of years later when they realized the vulnerability of these Zeppelins while flying over ground. These large, low-flying, slow-moving Zeppelins were easy target for bullets, rockets or a simple arrow transporting fire that would create these to erupt in flames. The German Navy in the other hand, continued with the use of airships, increased their fleet and attacked England early 1915. Due to the poor bomb load that these airships could carry, the Zeppelins were used to prove German's force over their allies more than the damaged cause by them. Germany was at these early stages of war delivering the war to England but soon the British Army increased their defense system developing observation patrols, searchlights, and wires to catch German Airships while tethered by balloons suspended in air and by creating fighter airplanes capable of flying higher than the German airships.

Due to the location of both countries, Germany had to fly 20-24hr round-trip over the North Sea and rapidly found that night flying would be advantageous. Navigation was a required skill and for this they developed and used radio direction-finding equipment in early 1916. However, the cold temperatures of those regions froze airships coolants, created ice on the hull and propeller. At this point the German Navy would only carry enough fuel for that missions plus a little of reserve but this was problematic if there was a navigation error or unexpected winds. It is amazing the fact that German lost more airships due to weather and mechanic problems than the ones brought down by British forces. Although Britain possessed and developed night fighter airplanes that took off sea platforms, France, Belgium, the Eastern Front and the Balkan Peninsula were also attacked by Germany mostly by daytime due to the fact that these other countries had minimum support to fight airships.

With the need to build airships and improve their building and flying skills, Germany had to build bigger, more powerful equipment to fly higher to avoid others defenses. By 1917 the Zeppelin building process was so well developed that it only took them 6 weeks to build one. Germans increased their airship volume size (from 22,000 cubic meters in 1914 to 55,000 in 1916) as well as engine power (from 600HP to 1,600HP by 1916). Figure 2.39 shows design and size evolution throughout their Zeppelins airships existence.

German logistics discovered that for the cost of one battleship they could build 80 airships. Although these monstrous airships frighten those under attack it was later discovered that German tactics weren't that successfully. From a total of 125 German airships, 79 were lost (63%), totaling 441 lost lives. With false/inaccurate battle reports to higher commands, the German realized that these airships were useful for reconnaissance over water but a failure as a land bomber.

The airplanes for those involved in early stages of WWI were designed mostly for observation missions. Most of these two-seats biplanes didn't had the performance or pay-load for much more. Graph on Figure 2.40 represents the number of aircraft available by the different countries at the start of WWI.

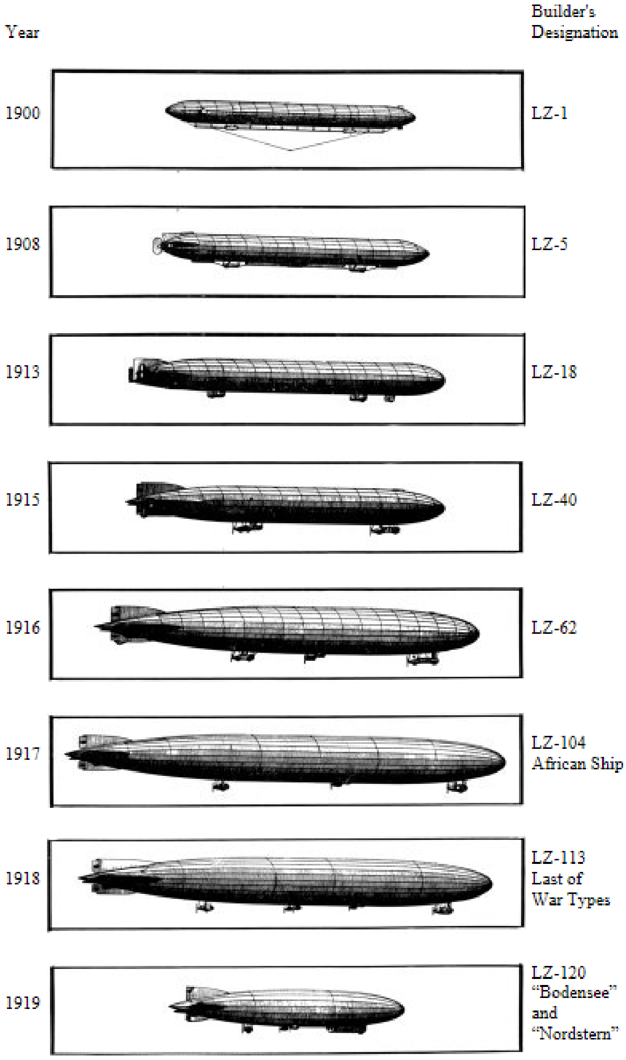

Figure 2.39 – 1900 to 1919 Zeppelins.[59]

[59] http://www.gutenberg.org/files/32570/32570-h/32570-h.htm; Retrieved 05/23/2014.

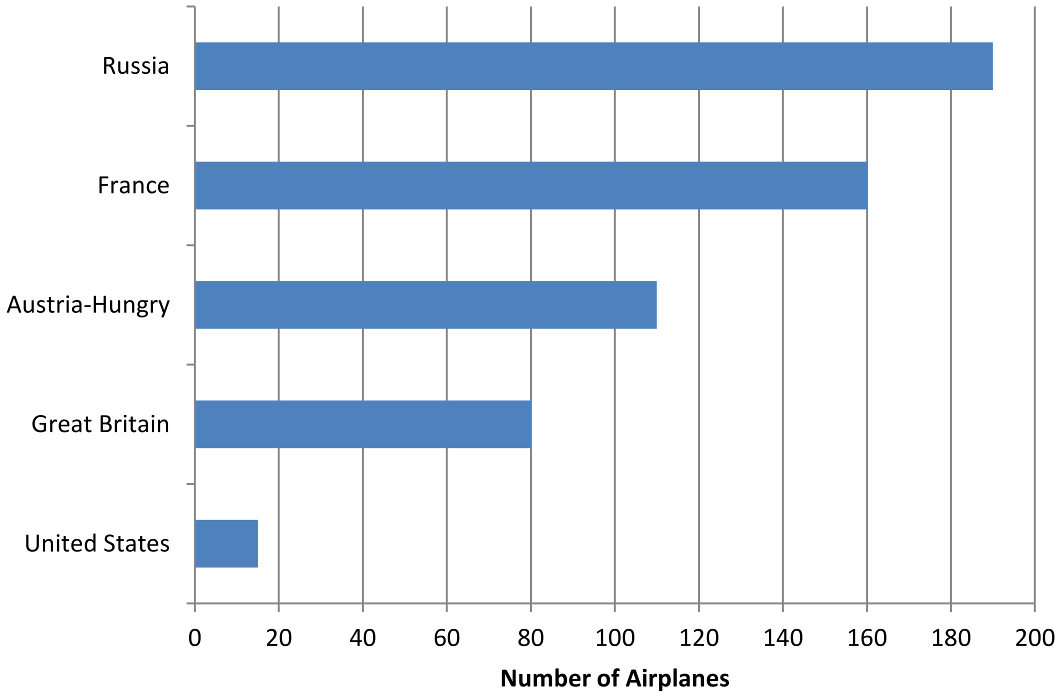

Figure 2.40 – Airplane availability at start of WWI

Table 2.1 represents the airplane year, their manufacturers name and model while Figure 2.40 and Figure 2.41 show the first and last of the Italian airplane manufactured throughout the WWI period. 1915 Caproni Ca.1 was a four-seater airplane with two 100HP engines as a puller and another engine as a pusher with machine guns and the option of bomb carrying; the 1918 Macchi M.7 a single pilot airplane with one 260HP engine with machine-guns.

Table 2.1 - Italian Airplanes in WWI.[60]

Year	Manufacturer and Model
1915	Caproni Ca.1
1917	Macchi M.5
1918	Caproni Ca.3
1918	Ansaldo A 1 Balila (Hunter)
1918	Macchi M.7

[60] http://www.militaryfactory.com/aircraft/ww1-aircraft-timeline.asp; Retrieved 05/02/2014.

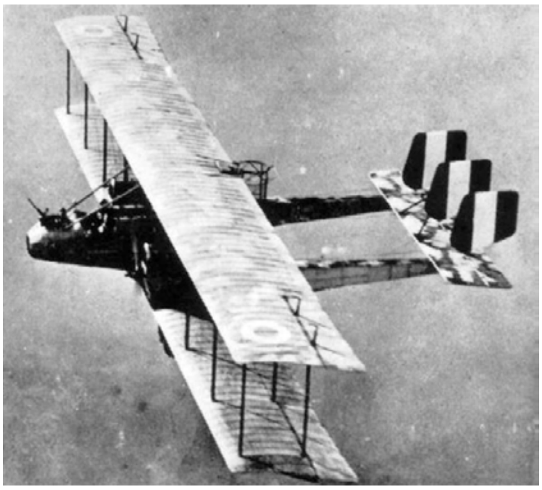

Figure 2.41 – 1915 Caproni Ca.1.[61]

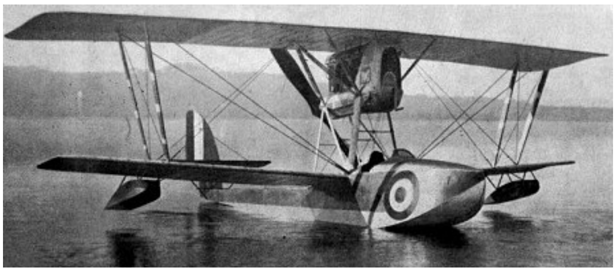

Figure 2.42 – 1918 Macchi M.7.[62]

Italy had some previous war experience in the Italy-Turkish War. Italy waterways and coast line gave upper-hand to the naval force for the military use of airplanes made domestically by Lohner, Macchi and some imported Curtiss (American airplanes).

The United States of America joined the war in April 1917 where the Army and Naval forces were recruited, trained and relocated to Europe. Some other pilots went to Canada or Britain to join the Canadian Royal Flying Corps and the British Royal Flying Corps. Others joined the French Foreign Legion Flying Corps (Légion Étrangére) while able to maintain their American citizenship. While in alliance with France, the Blériots, Nieuports and Spads airplanes were mostly used by American pilots.

Table 2.2 - American Airplanes in WWI. represents the airplane year, their manufacturers name and model while Figure 2.43 and Figure2.44 shows the first and last of the American airplanes manufactured throughout the WWI period. 1915 Curtiss JN-4 is a two seater airplane with one 90HP engine with no weapons installed (mostly used for training purposes); the 1918 Curtiss NC is a six seater airplane with

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[61] http://www.militaryfactory.com/imageviewer/ac/pic-detail.asp?aircraft_id=774&sCurrentPic=pi c1; Retrieved 06/02/2014.

[62] http://www.aviastar.org/pictures/italy/macchi_m-7.jpg; Retrieved 06/02/2014.

three 400HP engines as a puller and another one as a pusher with machine guns and the option of bomb carrying.

Table 2.2 - American Airplanes in WWI.[60]

Year	*Manufacturer and Model*
1915	Curtiss JN-4 (Jenny)
1916	Aeromarine 39
1917	Curtiss H-16
1917	Standard J-1
1918	Aeromarine 40
1918	Vought VE-7 Bluebird
1918	Curtiss NC (Navy Curtiss/Nancy Boat)

Figure 2.43 - 1915 Curtiss JN-4.[63]

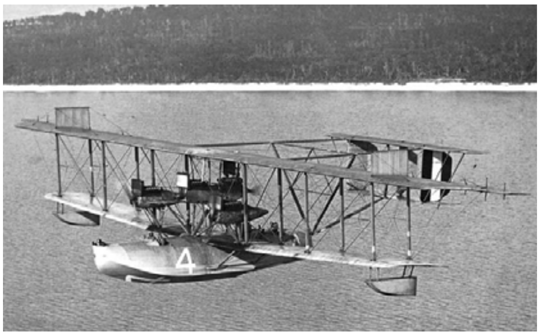

Figure2.44 - 1918 Curtiss NC.[64]

Great Britain joined the war in August 1914 with 4 squadrons from the British Royal Flying Corps. These officers flew to Amiens (France) and a couple of weeks later settled in Maubeuge. The first plane brought to war was a reconnaissance two-seat biplane named B.E.2a. More joined later with more airplanes identified as B.E.2, B.E.2b, Avro, Bristol and Sopwith.

Table 2.3 - Great Britain Airplanes in WWI. represents the airplane year, their manufacturers name and model while Figure2.44 and Figure 2.45 show the first and last of the British airplane manufactured throughout the WWI period. 1912 Royal

[63] http://www.westernspringshistory.org/wp-content/uploads/2014/03/WSHS-Curtiss-Jenny-Airpl ane.jpg; Retrieved 06/02/2014.

[64] http://www.militaryfactory.com/imageviewer/ac/pic-detail.asp?aircraft_id=918&sCurrentPic=pi c1; Retrieved 06/02/2014.

Aircraft Factory B.E.2 is a two seater airplane with one 90HP engine with the option of carrying a machine gun at the rear cockpit or bomb carrying; the 1919 Vickers Vimy is a three seater airplane with two 360HP engines with two machine guns (front and back) plus the option of bomb carrying.

Table 2.3 - Great Britain Airplanes in WWI.[60]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1912	Royal Aircraft Factory B.E.2	1917	Felixstowe F.2
1913	Avro 504	1917	Sopwith Dolphin
1914	Bristol Scout	1917	Armstrong Witworth F.K.8
1914	Sopwith Tabloid	1917	Airco DH.9
1915	Short Type 184	1917	Royal Aircraft Gactory S.E.5
1915	Sopwith Baby	1917	Sopwith Camel
1915	Vickers FB.5	1917	Bristol F.2
1915	Royal Aircraft Factory F.E.2	1917	Airco DH.4
1915	Airco DH.2	1917	Airco DH.5
1916	Sopwith Triplane	1918	Handley Page H.P. O/400
1916	Royal Aircraft Factory F.E.8	1918	Martin MB-1/Glenn Martin Bomber
1916	Sopwith 1-1/2 Strutter	1918	Blackburn R.T.1 Kangaroo
1916	Sopwith Pup	1918	Martinsyde F.4 Buzzard
1916	Royal Aircraft Factory R.E.8	1918	Sopwith Snipe
1916	Avro 523 Pike	1918	Sopwith Rhino
1917	Fairey Campania	1918	SSZ 65
1917	Avro 529	1918	NS7
1917	Beardmore WB III/SB 3	1918	Fairey III
1917	Felixstowe F.5	1919	Vickers Vimy

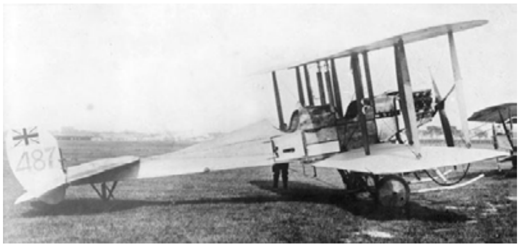

Figure 2.45 – 1912 Royal B.E.2.[65]

Figure 2.46 – 1919 Vickers Vimy.[66]

[65] http://www.militaryfactory.com/imageviewer/ac/pic-detail.asp?aircraft_id=1102&sCurrentPic= pic1; Retrieved 06/02/2014.

Austria-Hungary joined WWI with their airplanes but their main supplier (Lohner Aircraft Works) was building under German license. Some domestic industries kept making Hiero and Austro-Daimler engines to support their monoplanes and biplanes. Most of these airplanes were German design and the rest Austrian design. Their fleet included Albatros, Lohner-Daimler mono and bi-planes and Etrich-Taube monoplanes. Table 2.4 represents the airplane year, their manufacturers name and model while Figure 2.46 and Figure 2.47 show the first and last of the Austria-Hungary airplane manufactured throughout the WWI period. 1915 Lloyed C.II is a two seater airplane with one 145HP engine, with one machine guns in the front plus the option of carrying bomb(s); the 1918 Ufag C.I is two-seater with one 230HP engine with one or two machine guns in the front and another on the back.

Table 2.4 – Austria-Hungary Airplanes in WWI.[60]

Year	*Manufacturer and Model*
1915	Lloyd C.II
1915	Lohner B.VII
1916	Hansa-Brandenburg C.I (TypeLDD)
1916	Hansa-Brandenburg D.I (TypeKD)
1916	Lohner C.I
1917	Aviatik D.I (Berg D.I)
1917	Phonix C.I
1918	Ufag C.I

Figure 2.47 – 1915 Lloyd C.II.[67]

Figure 2.48 – 1918 Ufag C.I.[68]

[66] http://blog.sciencemuseum.org.uk/talkscience/files/2011/10/Vickers-Vimy.jpg; Retrieved 06/02/2014.

[67] http://www.militaryfactory.com/imageviewer/ac/pic-detail.asp?aircraft_id=739&sCurrentPic=_pic1; Retrieved 06/02/2014.

France had over 150 airplanes and 300 on orders at the start of WWI in 1914. France air fleet was operating in Rheims, Belfort, Verdun and Camp Châlons with the production of ballooning equipment as well as airplanes. France had the Breguet 14 and the Nieuport 17 airplanes in the beginning. Table 2.5 represents the airplane year, their manufacturers name and model while Figure 2.49 and Figure 2.50 shows the first and last of the French airplane manufactured throughout the WWI period. 1909 Bleriot XI is a single seater airplane with one 20-25HP engine with no weapons available; the 1920 SPAD S.XX is a two seater airplane with one 300HP engine with two machine guns in the front and another one in the back.

Table 2.5 - France Airplanes in WWI.[60]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1909	Bleriot XI	1917	Dorand AR
1914	Farman MF.11 Shorthorn	1917	SPAD S.XI
1915	Caudron G.4	1917	SPAD S.XIII
1915	Brequet Br.M5	1917	Brequet Bre.14
1915	Voisin Type 5	1917	SPAD S.XIII
1915	Morane-Saulnier Type N	1917	Nieuport 28
1915	Nieuport 11 (Bebe)	1918	Caudron R.11
1916	Nieuport 17	1918	SPAD S.XIV
1916	SPAD S.VII	1918	Salmson 2
1916	Hanriot HD.1	1920	SPAD S.XX (S.20)
1917	Nieuport 27		

Figure 2.49 - 1909 Bleriot XI.[69]

Figure 2.50 - 1920 SPAD S.XX.[70]

[68] http://upload.wikimedia.org/wikipedia/commons/0/0c/Phonix_UFAG_C.I.jpg; Retrieved 06/02/2014.

[69] http://upload.wikimedia.org/wikipedia/commons/8/8c/Bleriot_XI_Thulin_A_1910_a.jpg; Retrieved 06/02/2014.

[70] http://www.aviafrance.com/image.php?im=142; Retrieved 06/02/2014.

Germany's fleet of roughly 230 airplanes was short of the military goal of 1,000. With two aeronautical societies, the Imperial Aero Club and the Automobil-und Flugtechnische-Gesellschaft, with fours battalions and over 15 Army flying schools, the Germans used monoplanes and biplanes made by Albatros, Aviatik, Euler, Fokker, Gotha, Jeannin and Rumpler. Table 2.6 represents the airplane year, their manufacturers name and model while Figure 2.51 and Figure 2.52 shows the first and last of the German airplane manufactured throughout the WWI period. 1914 Albatros B.II is a two seater airplane with one 100HP engine with no weapons available; the 1918 LVG C.VI is a two seater airplane with one 200HP engine with two machine guns (front and back).

Figure 2.51 – 1914 Albatros B.II.[71]

Figure 2.52 – 1918 LVG C.VI.[72]

As history tells, Germany did not win the war. The various armies involved in WWI returned to their homes. Aviation in general with the development of airplanes and airships continued. It was proven that the airplane played a major role in WWI and therefore manufacturers continues with the intent of building faster, more capable airplanes.

Transatlantic flight by aircraft emerged after WWI, which had seen tremendous advances in aerial capabilities. From 8th to 31st May 1919, Commander Albert C. Read on a Curtiss seaplane NC-4 made a crossing of the Atlantic flying from the U.S. to U.K., with a stopover at Lisbon on 27th May; for this journey U.S. Navy disposed 60 warships along the route in order to direct the seaplane with use of both directional

[71] http://www.militaryfactory.com/aircraft/imgs/albatrosbii.jpg; Retrieved 06/02/2014.

[72] http://cdn-www.airliners.net/aviation-photos/photos/8/0/5/0806508.jpg; Retrieved 06/02/ 2014.

TSF radio communications and light naval projectors; - airplanes did not possess internal means of navigation.

Table 2.6 – Germany Airplanes in WWI.[60]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1914	Albatros B.II	1917	Rumpler C.IV
1914	Aviatik B.I	1917	Rumpler C.VII
1914	Zeppelin Z.XII (LZ-26)	1917	Rumpler C.VIII
1914	Hansa-Brandenburg B.I (Type D/FD)	1917	Rumpler D.I
1914	Rumpler B.I	1917	Zeppelin0Staaken R.VI
1915	Rumpler C.I	1917	Albatros J.I
1915	LVG B (Series)	1917	Hansa-Brandenburg W.12
1915	LVG C.II	1917	LVG C.V
1915	Rumpler G.I	1917	Gotha G.V
1915	Zeppelin L.10 (LZ-40)	1917	Zeppelin L.52 (LZ-98)
1915	Aviatik C.I	1917	Friedrichshafen G.III
1915	Fokker E (Eindecker) Monoplane	1917	Phonix D (Series)
1915	Albatros C.I	1917	Albatros D.V
1915	Albatros C.III	1917	Falz D.IIII
1915	AGO C.II	1917	Siemend-Schuckert D.III
1915	AEG C.IV	1917	Albatros D.III
1916	AEG G.IV	1917	Fokker Dr.I (Dreidecker) Triplane
1916	Albatros C.V	1917	Albatros D.Va
1916	Albatros D.I	1917	Albatros C.X
1916	Albatros D.II	1918	Junkers CL.I
1916	Siemend-Schuckert D.I	1918	Fokker D.VIII
1916	DFW C.V	1918	Fokker D.VII
1916	Zeppelin L.32 (LZ-74)	1918	Siemens-Schuckert D.IV
1916	Gotha G.IV	1918	Halberstadt CL.IV
1916	Rumpler 6B	1918	LVG C.VI
1916	Rumpler C.III		

The conjunction of reference points through a trajectory line with the ability to skillful modifications on astronomy navigation mathematical formulas was firstly applied by Portuguese airmen Gago Coutinho and Sacadura Cabral at the quest of aerial flight navigation. With such knowledge, these airmen managed to prepare greater part of their route calculations before the flight, leaving only another quite material part to be done in the air. Such internal mean of navigation, could easily allow any pilot to know the exact coordinates of their location, in real time.

Portuguese early Aviation contributed to such original conceptions by which astronomical navigation could as well to serve aerial routes on near future, as they served sea routes on the past. From 1922 onwards, Portuguese Aviation proved to the World of Aviation that flight navigation could be easily made with a modified sextant (and a path corrector), in a comfortable way while flying and with great accuracy.

Upon an aeronautical exhibition in Frankfurt in 1909 Lieutenant Engineering Pedro Fava Ribeiro de Almeida with the support of 16 other members founded the Aero Clube de Portugal in December 11th that same year. It wasn't until 1912 following France desired to include aviation in the Army that Portuguese citizen Dr. António José de Almeida, proposed the creation of a Military Aviation division to support the Army and the Navy. The first airplane, an Avro 500 was purchased in England in May of 1912 and delivered in Portugal a few months later christened the "República". Shortly after a new Maurice Farman MF4 biplane was purchased in France christened the "Casta Susana" and another airplane, a Deperdussin Type B, was given by Lieutenant Colonel Albino Costa.

Portugal joined the FAI (Fédération Aéronautique Internationale) in January 28th 1913 and after various studies and proposals the first Military Aviation School was settled in Vila Nova da Rainha and inaugurated in 1916 entitled "Escola Militar de Aviação" Figure 2.53.

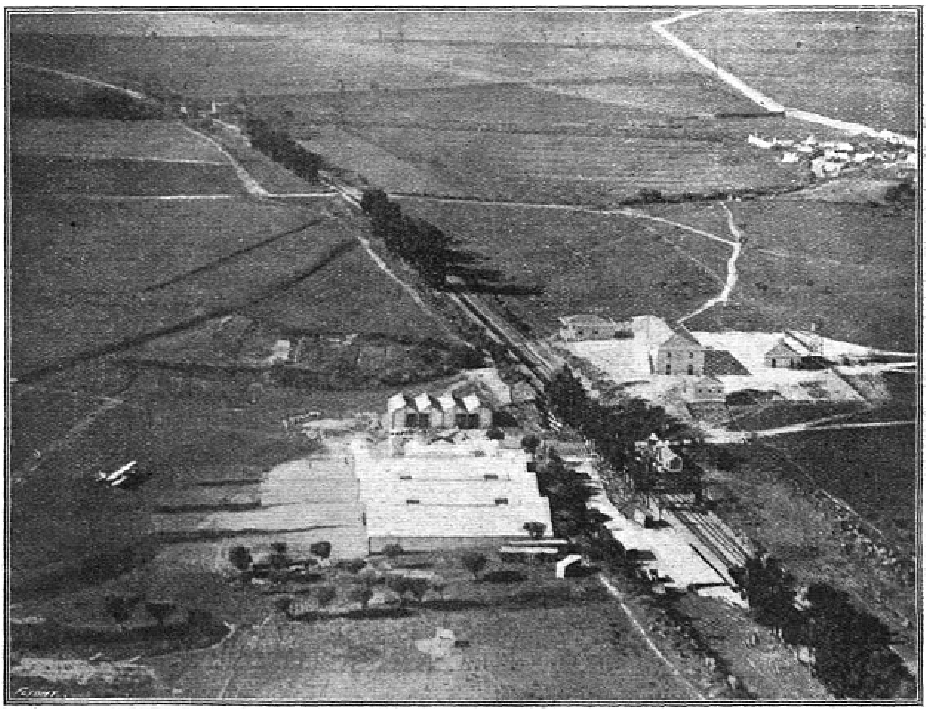

Figure 2.53 – Aviation School at Vila Nova da Rainha. (Cardoso, 1981)

An important figure in the Portuguese aviation was Sacadura Cabral (Figure 2.54) born in May 23rd of 1881 in Celorico da Beira in Serra da Estrela area which joined the Portuguese Navy at the early age of 16.

Figure 2.54 – Sacadura Cabral portrait. (Neves, Barata, & Silva, 2016)

Various outstanding achievements took place between 1897 and 1912 when he met Gago Coutinho in a mission in Angola with the intent to delineate the eastern border of that country. When back to Portugal in 1915, Sacadura Cabral and ten other officers were sent abroad for flight training and pilot licenses. Some went to the Signal Corps Aviation School in San Diego, California (USA) and others to the Centre d'Aviation Militaire de Chartres in France. Sacadura Cabral graduated as a pilot on March 9th of 1916 and for a few more months, he continues his training achieving different ratings on Hydroplanes and faster airplanes. This particular time-frame matched the opening of the Aviation School in Portugal and Sacadura Cabral was invited to become one of the school flight instructors (Figure 2.55).

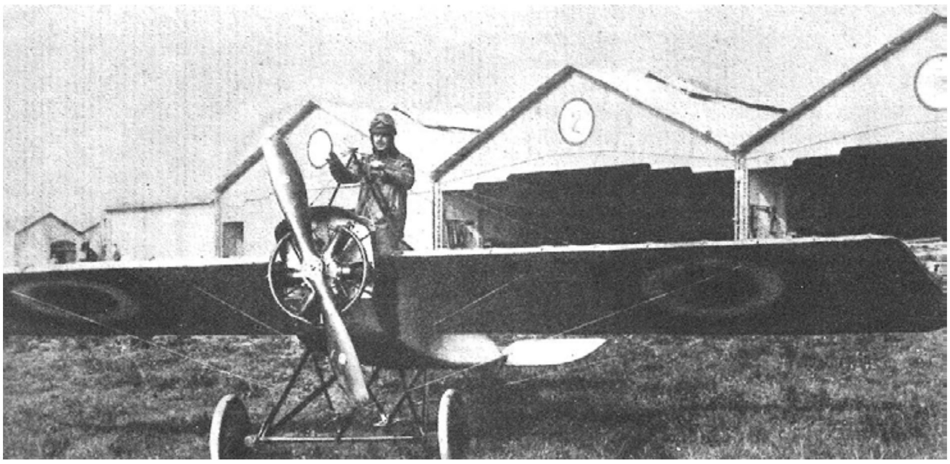

Figure 2.55 – Sacadura on a Morane Saulnier airplane, Vila Nova da Rainha,1917. (Cardoso, 1981)

Shortly after, Germany invaded the region of Niassa in Angola and the Portuguese Government decided to send a Squadron to cooperate with the local army and protect economic and political interests. With this decision, Sacadura Cabral was sent to France to acquire all necessary equipment for this Squadron. In the meantime, Sacadura has the opportunity to meet Lieutenant Albert C. Read where they discussed Intercontinental Journeys. As a pilot, an instructor and an innovator, Sacadura Cabral proposed to the Navy Minister a trip over the Atlantic from Lisbon, Portugal to Rio de Janeiro, Brazil with the intent to promote the friendship between both of these countries since the Discovery era of Christopher Columbus. In June 6th of 1919, the Navy Minister made it official with the government and instructed Sacadura Cabral to plan this Atlantic crossing (Figure 2.56).

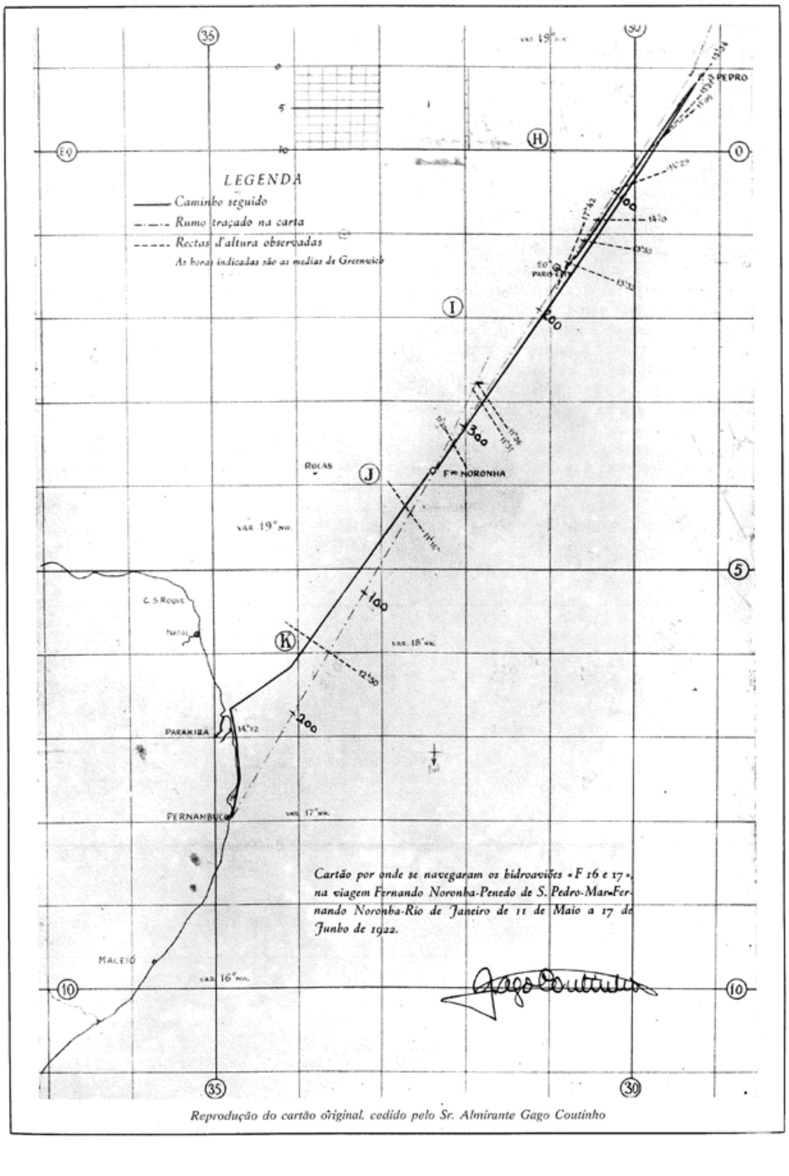

Figure 2.56 – Reproduction of the original card of the Lisbon to Rio de Janeiro Trip. (Cardoso, 1981)

The first set of plans presented by Sacadura Cabral showed some questionable data regarding the accuracy of navigation due to drifts and weather conditions. With this in mind, he engaged with Gago Coutinho (Figure 2.58) and to address this navigation issues ultimately leading to the artificial bubble sextant (Figure 2.57 – Precision Sextant used by Gago Coutinho.) and later on a tool capable of compensating for the wind drift later known as the path corrector (Figure 2.59).

Figure 2.57 – Precision Sextant used by Gago Coutinho. (Silva, Barata, & Neves, 2016).

Figure 2.58 – Gago Coutinho portrait. (Barata, Mendes, Morgado, Neves, & Silva, 2009)

Various short flights took place to prove function of these navigation tools and on March 22nd of 1921, Sacadura Cabral, Gago Coutinho, Ortins de Bettencourt and Roger Soubiron made an experimental flight from Lisbon to Madeira using three ships to control and verify its position. Upon 7 hours and 30 minutes, this attempt was proven to be a success and this gave them the ultimately trust on these navigation tools.

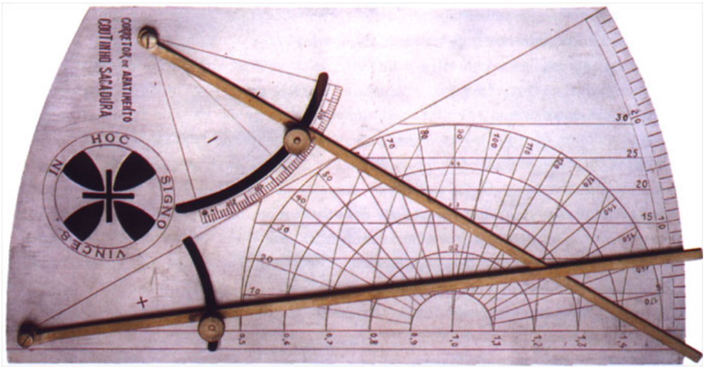

Figure 2.59 – Path Corrector. (Silva, Barata, & Neves, 2016).

In September 4th of 1921, Sacadura Cabral went to England's Frairey's airplanes manufacturers and they developed a modified Fairey III-D (aka F III-D) for this particular trip. The agreement also included two more F III-D airplanes to be manufactured and delivered in the meantime. The first F III-D was sent disassembled form England to Portugal in January of 1922 and assembled at the Naval Aviation Center in Portugal. On his return from England, Sacadura met with the Navy Minister where he was told to start the Cross-Atlantic trip as soon as possible.

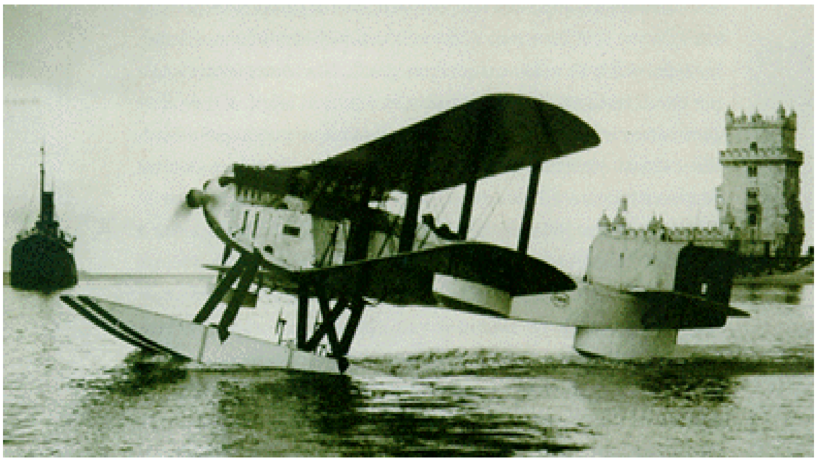

Figure 2.60 – "Lusitânia" Hydroplane. (Barata, Mendes, Morgado, Neves, & Silva, 2009)

After two very busy and exciting weeks planning the flight and observing weather and ocean conditions, Gago Coutinho (navigator and observer) and Sacadura (pilot) took-off for the first projected stop at the land of Penedos near the Brazilian coast for re-fuel. Upon landing, one of the floats on the "Lusitania" was damaged and caused the airplane to sink.

Figure 2.61 – Gago Coutinho and Sacadura Cabral. (Barata, Mendes, Morgado, Neves, & Silva, 2009)

The Portuguese government helped them by sending another Fairey airplane previously delivered. As if that wasn't enough, a little bit later, that 2nd Fairey showed engine problems causing it to land and shortly after the floats started to sink – both passengers were rescued by a British freighter. On June 5th, they received a 3rd Fairey III-D to continue on their trip and finally reached the point of destination on June 17th of 1922.

As the innovator and adventurer Sacadura Cabral was, he proposed an Aerial Circumnavigation trip previously done by boat at the command of Fernão de Magalhães held between the years 1519 and 1522. Due to money and bureaucratic problems this trip never took place and in November 15th of 1924, Sacadura Cabral died somewhere in the English Channel at the commands of a Fokker 4146 from Amsterdam to Lisbon (Neves, Barata, & Silva, 2016).

From November 8th 1917 to November 11th 1918 a series of peace negotiations took place starting with Germany's Eastern Front with Russia, followed by the Bulgarian/Macedonian line, by Mudras on the island of Lemnos, by Austria-Hungary and later by Central Powers in Germany. The need for war supplies was no longer viable between government entities and manufacturers therefore settlements were created resulting in mass personnel laid-off and company doors closed (some definitely).

A major conference took place in 1919-1920 in the city of Versailles in France with the intent to define and gather peace negotiation details. Due to the fact that Russia was in civil war right after WWI ended, representatives of France, United States, Italy and Britain attended this conference and defined the League of Nations (Christian, 1995).[73] As a result of this conference a fifteen-part treaty was formally written and accepted by those attending this conference. This treaty brought public humiliation to Germany relinquishing land, colonies, money, rights and part of their freedom. As part of this document included well defined air clauses prohibiting Germany from having any sort of air force demanding immediate control on all bombing planes (estimated around 15,000) and over 2,500 airplane motors – these were distributed to those affected by the war (Christienne & Lissarague, 1986).

As the need for military flights and the creation of manufacturing combat equipment was prohibited, aviators and manufacturers rapidly focused on the growing need for long-distance flights. These long-flights proved the manufacturing, airframes and motors experience and developments as well as personnel as pilots, navigators and mechanics. Prior to the Versailles conference, while WWI was still undergoing, the United States of America were developing an airplane able to fly across the Atlantic Ocean with the intent of bringing supplies and surveillance. This partnership created the Navy/Curtiss airplane designated by “NC” mentioned as “Nancy”. A total of four airplanes were built with 126ft wingspan, 68feet long with a total weight of 28,000 pounds.

Due to the fact that the war ended, the government and Curtiss Aeroplane Company continue their efforts on building these airplanes. The maiden flight tool place in October 1918 and in November 1918 the NC-1 set established a new world record by transporting no fewer than 51 passengers. This flight although successful showed that there wasn’t enough power for a transatlantic flight – more engines were added to this airplane frame in different tractor versus pusher configurations. These new airplanes were then identified as NC-TAs as Nave/Curtiss-Transatlantic (see Figure 2.62). The plan was to fly from Rockaway in the United States of America, to Halifax in New Scotia, to Trepassy bay in Newfoundland, to Fayal, then to Ponta Delgada in the Portuguese Azores Islands, to Lisbon in mainland Portugal to end in Plymouth in England (see Figure 2.63). Although three of these NC-TAs airplanes left the United Stated, only NC-4 completed its flight due to engine problems and bad weather.

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[73] pp. 77.

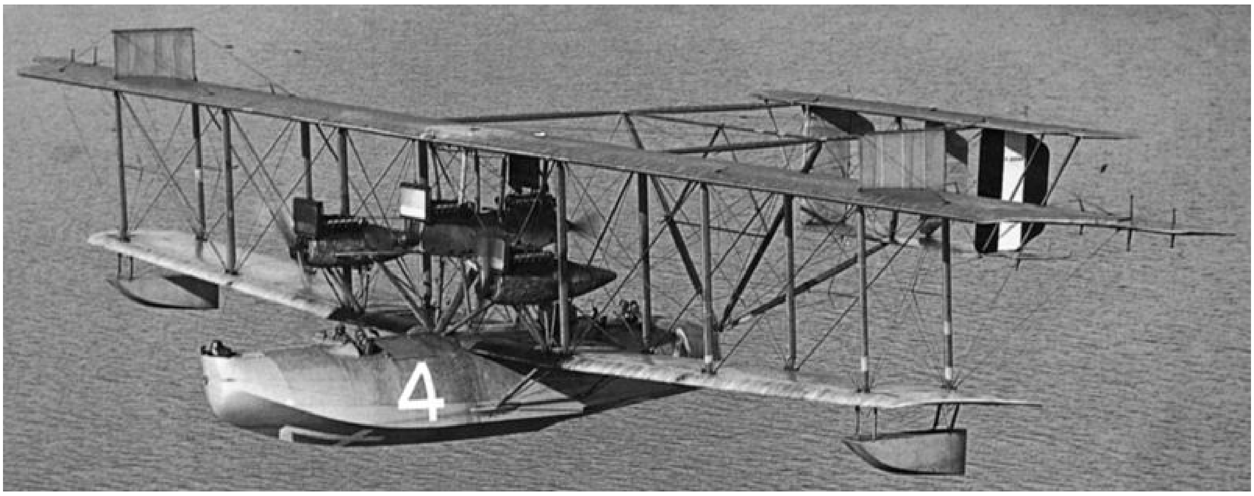

Figure 2.62 – Navy and Curtiss Aeroplane NC-4. [74]

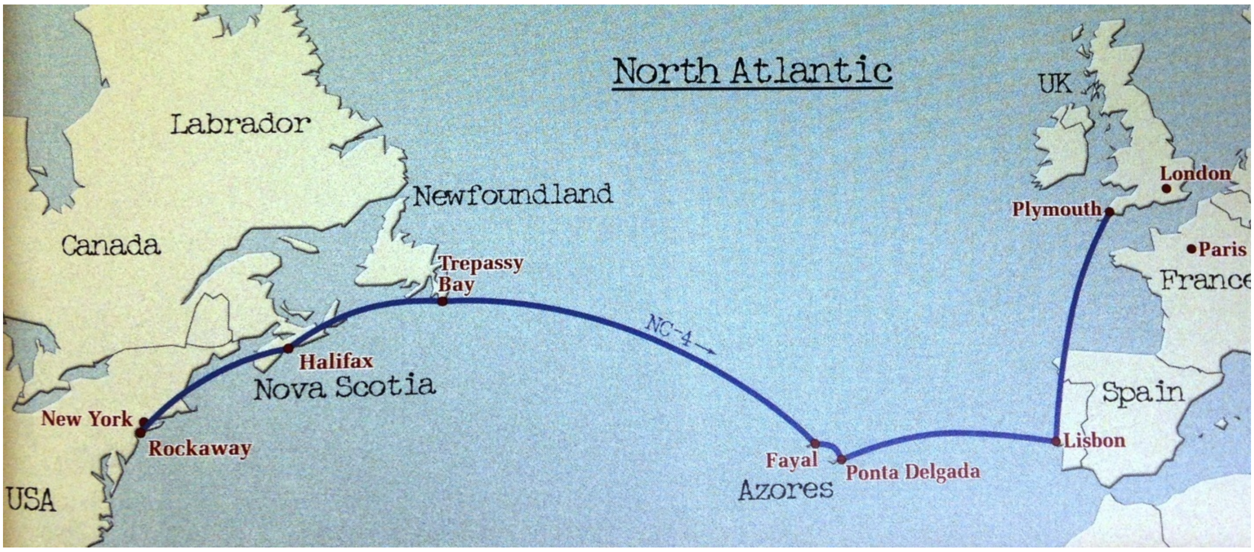

Figure 2.63 – NC-4 TAs Route (Jeppesen, 2006). [75]

The *Daily Mail* re-opened the competition to fly across the "pond" in 1919 and eleven entries signed for this event. The US Navy chose not to compete for this prize because the NC's were government sponsored airplanes. This prize was only for those that helped Britain and the Allies against Germany and "*to be awarded to the aviator who shall first cross the Atlantic in an aeroplane in light from any point in the United Stated, Canada, or Newfoundland to any point in Great Britain or Ireland, in 72 consecutive hours. (The flight may be made either was across the Atlantic.)*" (Lewis, 1970). In June 14th, 1919 John Alcock and Arthur Whitten Brown

[74] http://www.patriotspoint.org/news_events/wp-content/uploads/2011/05/curtiss_nc-4.jpg; Retrieved 06/05/2014.

[75] pp. 5-7.

flew from Newfoundland to Ireland completing the first non-stop transatlantic flight in 15hours and 57minutes.[76] They used a modified bomber called Vimy (see Figure 2.64) while powered by two Rolls Royce Engines, with 68feet wingspan and over 1,000 gallons of fuel on take-off. They won the *Daily Mail* prize and were knighted by King George V. This success flight brought great pride to the British society acknowledging the fact that it was a British design, construction and engines that allowed this flight to happen.

Figure 2.64 – Vickers Vimy aircraft of Captain John Alcock and Lieut. A.W. Brown.[77]

Other remarkable flights took place shortly after following the *Daily Mail* idea of money prizes and recognition. From November 12th, 1919 to December 10th Lieutenants Ross Macpherson Smith and his brother Keith Macpherson Smith with two mechanics flew from Hounslow, England to Darwin, Australia logging 135 hours and 55 minutes of flight time.[78]

Due to the peace agreement signed, Germany couldn't use motors for their airplanes, therefore gliding was heavily promoted for science and sport reasons. Various meeting and rallies took place shortly after that announcement bringing new

[76] Inscription, Alcock and Brown memorial, near Clifden, Ireland.

[77] http://upload.wikimedia.org/wikipedia/commons/0/0a/Vickers_Vimy_Alcock_and_Brown.jpg ; Retrieved 06/06/2014.

[78] http://www.flightglobal.com/pdfarchive/view/1919/1919%20-%200671.html; Retrieved 06/06/2014.

records and supporting the need to keep developing their airplanes (non-powered).[79] On the other side of the Atlantic, the United States of America dedicated themselves to an activity identified as barnstorming. The surplus of war trained pilots and airplane equipment brought the idea of competing in long distances (for money, adventure and recognition) plus the fact that they could fly from town to town showing their airplanes performances and pilot abilities while offering rides for a living. The airplane of choice was the Curtiss Jenny where they could be bought for $3,250 instead of the $8,000 price tag when at war. Used airplanes became more frequent and therefore the initial price tag came down to a $250 - $500 price range. Trying to get public to notice their abilities, pilots formed teams and joined flying circuses performing all over while defying death walking on the airplanes wings while in flight (Winchester, 2004).

On the other hand, the US Army Air Service kept developing new engines and airplane designs for altitude, speed and endurance records. The Army gave favor to records like the first flight around the border of the United States, a round trip between the continent and territorial Alaska, the sinking of a captured battleship using bombs dropped from airplanes, the first nonstop transcontinental flight across US and the first aerial refueling system. The next goal was to fly around the world[80] to show all nations the need to keep developing aviation for commercial and military reasons therefore four Douglas World Cruisers were ordered and built in Santa Monica, California. This particular airplane was a 2 seater, open cockpit with wood construction wings and a tubular steel fuselage (see Figure 2.65). The route, very well planned, included all parts for these airplanes as well as dedicated mechanics for these airplanes. On April 6th of 1924 the Boston, Chicago, New Orleans and Seattle named airplanes took off from Lake Washington, Seattle and initiated their route. Seattle airplane crashed into a mountain after leaving Chignik, Alaska and Boston airplane had a forced landing between Orkneys and Faroe Islands due to a loss of oil pressure – all pilots were rescued. The Chicago and New Orleans airplanes

[79] Aviation, Volume 12, McGraw-Hill Publishing Company, 1922, Princeton University, Retrieved 06/06/2014.

[80] Several countries were vying to be the first to complete a flight around the world. In 1922, British had made one unsuccessful around-the-world air flight attempt; in 1923, a French team had tried; the Italians, Argentines, Portuguese and British also announced plans for a world-circling flight.

completed in September 28th of that same year the flight around the world logging 26,345 miles with 371hours and 11 minutes of flight time.[81]

Figure 2.65 – "New Orleans" Douglas World Cruiser.[82]

One important factor for aviation in general was its purpose and among those we can identify the need for mail deliverance. The first scheduled airmail delivery was under British territory between London and Windsor in September 9th and in late 1918 became international while flying to Germany (Baldwin, 1961). The United States initiated their mail service in May 1918 using Curtiss JN4 and JNS biplanes. Although it started by military forces rapidly became a civil owned activity for commercial reasons. With vision to business and innovation, a French businessman named Pierre-Georges Latécoère started to plan commercial routes within France and French territories. It started between Paris, Le Mans and St. Nazaire expanding their routes to Barcelona, Spain in December 1918. With the intent to exchange mail with Africa French territories, they started to plan flights to Alicante in the south side of Spain and in March 1919 planned for deliver to Dakar. It was step-by-step process being able to reach Casablanca by September 1919 and finally Dakar in 1925. This final route covered 1,600 miles between Toulouse and Dakar which meant at least four stops to re-fuel and perform aircraft maintenance (Franix-Reichel, 1928).

[81] http://airandspace.si.edu/collections/artifact.cfm?id=A19250008000; Retrieved 06/06/2014.

[82] http://www.dmairfield.org/Collections/Klein%20Collection/Army/images/DWC-New-Orleans. jpg; Retrieved 06/06/2014.

Germany airline company Deutsche Luft-Reederei, with permission from the Peace Conference of 1919, initiated in February 1919 mail service for newspapers, followed by mail and within a week time-span transporting passengers between Berlin and Weimar. Fast growth company expanded their routes across Germany and focused more and more on carrying passengers. As a grown industry various groups and companies applied for airline licenses and grew accordingly. As any successful venture, two companies joined efforts and created Deutsche Lufthansa in January 1926. This venture allowed them to become bigger and buy other competitors, their airplanes and their licenses (Wagner, 1987).

The United States Post Office took the responsibility for airmail deliverance and in 1918 they had over 700 flights covering more than 80,000 miles. In 1919 numbers multiplied to 1,600 flights with 400,000 miles flown. With the mindset to provide airmail service throughout the entire continent, the US Postal Office started with flight phases from New York to Cleveland, from Cleveland to Chicago, from Chicago to Omaha and from Omaha to San Francisco. In September 1920 the first transcontinental flight took close to 83 hours to complete but shortly after in February 1921 a coast-to-coast flight with three pilots aboard in rotation took 33hours and 20minutes. By 1925 the US Postal Office had 745 people supporting their Air-Mail service and a fleet of 96 aircrafts. As this was a fast growing industry, there was the need to regulate this industry and therefore the Air Mail Act of 1925 and the Air Commerce Act of 1926 were formally created and published. The Air Mail Act of 1925 allowed the Post Office to sub-contract other airliners for airmail services and the Air Commerce Act in 1926 allowing sub-contractors to maintain and operate airways, providing for pilot licensing, airworthiness rules and federal activities in the civil aviation (Kent Jr, 1980).

In spite of the agreement at the end of World War I, Germany invaded Poland on September 1st of 1939 with the intent of gaining control of the Free City of Danzig and the Polish Corridor linking Poland to the Baltic Sea. The fast-paced assaults using infantry and tanks while supported by aircraft fighters and bombers were strategic missions to destroy several Polish military facilities. Germany used mainly the Messerschmitt Bf109 and Bf110 aircrafts fighters (single and twin-engine respectively), the Junkers Ju 87 Stuka dive bombers, the Heinkerl He 111 and Dornier Do 17 bombers. In September 2nd on a futile attempt to respond to that attack Poland retaliated while attacking Germany territory using Panstwowe Zaklady Lotnicze (aka PZL) P.11a, P.11c fighters and P-23 Karas bombers but as expected without any success. As described in **Erro! A origem da referência não foi encontrada.** and **Erro! A origem da referência não foi encontrada.**, it is visible that Poland air force was far away from Germany's vast power in equipment and man power available to this war. Figure 2.66 and Figure 2.67 show the first and last airplane used by each Poland and Germany this time of war.

Table 2.7 - Polish Airplanes in WWII.[83]

Year	*Manufacturer and Model*
1932	PZL P.11
1936	PZL. P-23 Karas

Figure 2.66 - Polish P11[84] and P-23 Airplanes[85].

Germany designed, built and used 105 different airplanes throughout WWII. All of these models were mass-produced therefore we can only imagine the real number of airplanes available to their troops.

Table 2.8 - German Airplanes in WWII. Part I. [83]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1932	Junkers Ju 52	1943	Arado Ar E.555
1933	Heinkel He 70 (Blitz)	1943	Arado Ar e.654 (Skorpion)
1933	Heinkel He P.1077 (Julia)	1943	Arado Ar Projekt II
1934	Arado Ar 68	1943	Arado Ar TEW 16/43-13
1934	Dornier Do 23	1943	Arado Ar TEW 16/43-15
1935	Heinkel He 112	1943	Arado Ar TEW 16/43-19
1935	Heinkel He 51	1943	Arado Ar TEW 16/43-23

[83] http://www.militaryfactory.com/aircraft/ww2-aircraft.asp ; Retrieved 9/28/2014.

[84] http://forum.warthunder.com/uploads/monthly_05_2014/post-354159-0-96932700-1401211483.jpg; Retrieved 11/5/2014.

[85] http://historykon.pl/wp-content/uploads/2013/12/pzl_pzl-23_karas.jpg; Retrieved 11/5/2014.

Table 2.9 - German Airplanes in WWII. Part II. [83]

Year	Manufacturer and Model	Year	Manufacturer and Model
1936	Arado Ar E.500	1943	Blohm and Voss P.192
1936	Heinkel He 111	1943	Heinkel He 219 Uhu
1936	Henschel Hs 123	1943	Junkers Ju 187
1936	Junkers Ju 86	1943	Junkers Ju 188 Rache (Avenger)
1937	Arado Ar 195	1943	Junkers Ju 252
1937	Arado Ar E.561	1943	Junkers Ju 352 (Herkules)
1937	Dornier Do 24	1943	Junkers Ju 390 (New York Bomber)
1937	Dornier Do17 (Flying Pencil)	1943	Luftwaffe Mistel / Beethoven-Gerat
1937	Fieseler Fi 156 Storch (Stork)	1943	Messerschmitt Me 209-II
1937	Junkers Ju 87 (Stuka)	1943	Messerschmitt Me 323 Gigant
1937	Messerschmitt Bf 108 Taifun	1943	Messerschmitt Me 410 Hornisse
1937	Messerschmitt Bf 110 Zerstorer	1944	Arado Ar 234 (Blitz)
1938	Blohm and Voss Bv 141	1944	Arado Ar E.381 (Kleinstjager)
1938	DFS 230	1944	Arado Ar E.580
1938	Dornier Do 18	1944	Arado Ar E581.4
1938	Dornier Do 22	1944	Blohm and Voss Bv 238
1938	Focke-Wulf Fw 200 (Condor)	1944	Blohm and Voss P.208
1938	Lippisch P.13A	1944	Fieseler Fi 103R (Reichenberg)
1939	Arado Ar 196	1944	Focke-Wulf Ta 154 Moskito
1939	Dornier Do 215	1944	Heinkel He 343 (Strabo 16)
1939	Flettner Fl265	1944	Heinkel Lerche (Lark)
1939	Heinkel He 115	1944	Horton Ho X (10)
1939	Heinkel He 176	1944	Junkers Ju 287
1939	Heinkel He 178	1944	Junkers Ju 388
1939	Junkers Ju 88	1944	Messerschmitt Me 163 Komet
1940	Arado Ar 240	1944	Messerschmitt Me 264 Amerika
1940	Arado Ar E.530	1944	Messerschmitt Me 328
1940	Blohm and Voss Bv 138	1944	Messerschmitt Me P.1101
1940	Focke-Wulf Fw 187 Falke	1944	Messerschmitt Me P.1101/92
1940	Focke-Wulf Fw 190 Wurger (Shrike)	1944	Messerschmitt Me P.1106
1941	Arado Ar 232 Tausendfussler	1945	Arado Ar E.560
1941	Blohm and Voss Bv 222 Wiking	1945	Arado NJ-1 Nacht Jager
1941	Focke-Achgelis Fa 223 Drache	1945	Bachem Ba 349 Natter (Viper)
1941	Gotha Go.242	1945	Blohm and Voss Bv 155
1941	Gotha Go.244	1945	Blohm and Voss P.212
1941	Heinkel He 280	1945	Dornier Do 335 Pfeil (Arrow)
1941	Henschel Hs P.75	1945	Focke-Wulf Ta 152
1941	Messerschmitt Me 321 Gigant	1945	Focke-Wulf Ta 183 (Huckebein)
1942	Dornier Do 217	1945	Gotha Go P.60A/B
1942	Flettner Fl 282 Kolibri	1945	Gotha Go P.60C

Table 2.9 - German Airplanes in WWII. Part III. [83]

Year	Manufacturer and Model	Year	Manufacturer and Model
1942	Focke-Wulf Fw 191	1945	Heinkel He 162 Volksjager
1942	Heinkel He 111Z (Zwiling)	1945	Heinkel He P.1078B
1942	Heinkel He 177 Greif (Griffin)	1945	Heinkel He P.1078C
1942	Messerschmitt Me 262 Schwalbe	1945	Henschel Hs 132
1942	Messerschmitt Me 309	1945	Horten Ho IX / Horten Ho 229
1943	Arado Ar E.340		

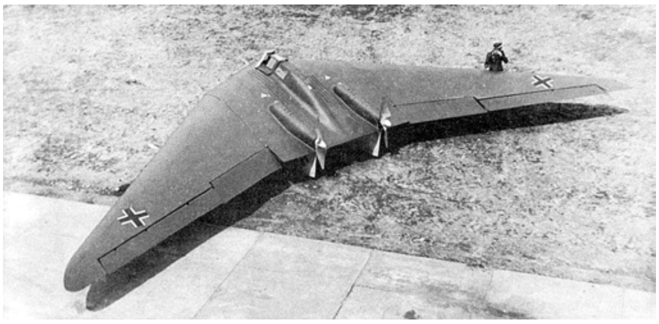

Figure 2.67 - German Ju52[86] and Ho 229 airplanes[87].

Great-Britain and France sent ultimatums to Germany and after no response the declare war against Germany on September 3rd. Australia and New Zealand teamed-up with Great-Britain and on the 4th the Britain's Air Force raided Germany naval facilities at Wilhelmshaven and Cuxhaven discovering strong resistance loosing various aircraft and personnel. With the attacks continuing from Germany, the Polish air-force was damaged, out-numbered and out-classed by the German air divisions giving the Germans the advantage of raiding railroads, roads, bridges and troops limiting the Polish response to their attacks (Dunmore, 1995). **Erro! A origem da referência não foi encontrada.**, **Erro! A origem da referência não foi encontrada.** and **Erro! A origem da referência não foi encontrada.** show different airplane models built in Australia, France and Great-Britain on this WWII era. Figure 2.68, Figure 2.69 and Figure 2.70 show the first and the last airplane used by Australia, France and Great Britain on this time of war, respectively.

[86] http://www.warbirdalley.com/images/ju52-02.jpg; Retrieved 11/6/2014.

[87] http://img404.imageshack.us/img404/484/horten2motoresaelice.jpg, Retrieved 11/6/2014.

Table 2.9 - Australia Airplanes in WWII.[83]

Year	*Manufacturer and Model*
1939	CAC Wirraway
1941	CAC Wackett
1941	CAC Woomera (A23)
1942	CAC Boomerang

Figure 2.68 - Australia Wirraway[88] **and Boomerang Airplanes**[89]**.**

Table 2.10 - France Airplanes in WWII.[83]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1928	Liore-et-Olivier LeO 25	1939	Bloch MB.150 (series)
1933	ANF Les Mureaux (Series)	1939	Dewoitine D.520
1935	Bloch MB.210	1939	Loire-Nieuport LN.401/LN.411
1936	Dewoitine D.500	1940	Amiot 354
1938	Liore-et-Olivier LeO 45	1940	Amiot 354
1938	Morane-Saulnier MS 405/406	1940	Arsenal VG-33
1938	Potez 630 (Series)		

[88] http://www.warbirdregistry.org/wirraregistry/images/wirraway-a20722-1.jpg, Retrieved 11/6/2014.

[89] http://www.casa.gov.au/wcmswr/_assets/main/casadata/register/images/aircraft/bom.jpg, Retrieved 11/6/2014.

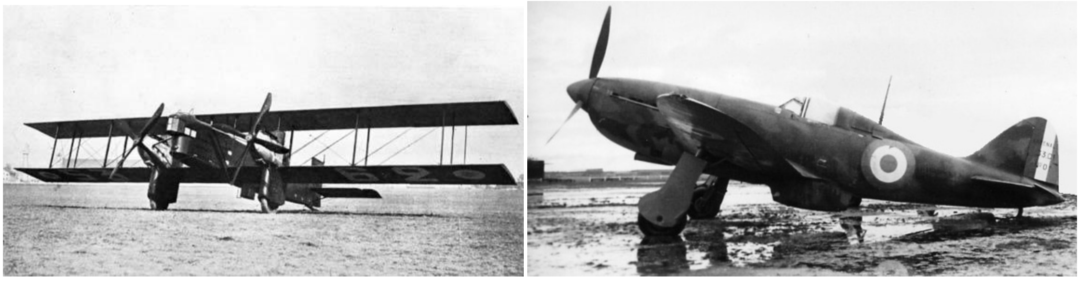

Figure 2.69 - FrenchLeO 25[90] and VG-33 Airplanes[91].

Table 2.11 - British Airplanes in WWII.[83]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1924	Armstrong Whitworth Siskin	1938	Vickers Wellington
1929	Blackburn Ripon	1939	Bristol Beaufighter
1931	Hawker Fury (I & II)	1939	Hawker Tornado
1932	de Havilland DH.82 Tiger Moth	1939	Sauders-Roe A.36 Lerwick
1933	Avro 621 Tutor	1940	Avro Manchester
1934	Blackburn Baffin	1940	Bristol Beaufort
1935	Bristol Blenheim	1940	Fairey Fulmar
1935	Gloster Gauntlet	1940	Handley Page Halifax
1936	Armstrong Whitworth Ensign	1940	Miles M.20
1936	Avro Anson	1940	Westland Whirlwind
1936	Fairey Swordfish	1941	Armstrong Whitworth Albermarle
1936	Sauders-Roe A.27 London	1941	Hawker Sea Hurricane
1936	Supermarine Walrus	1941	Hawker Typhoon
1937	Airspeed Oxford	1941	Short Stirling
1937	Armstrong Whitworth Whitley	1942	Airspeed Horsa
1937	Boulton Paul Defiant	1942	Avro Lancaster
1937	Fairey Battle	1942	de Havilland DH.98 Mosquito
1937	Gloster Gladiator	1942	Supermarine Seafire
1937	Hawker Hurricane	1943	Bristol Buckingham
1937	Short S25 Sunderland	1943	Fairey Firefly
1937	Supermarine Stranraer	1944	Hawker Tempest
1937	Vickers Wellesley	1944	Westland Welkin
1938	de Havilland DH.91 Albatross	1945	Fairey Spearfish
1938	Handley Page Hampden	1945	Hawker Sea Fury / Fury
1938	Supermarine Spitfire		

[90] http://www.aviafrance.com/image.php?im=164, Retrieved 11/6/2014.

[91] http://www.avionslegendaires.net/Images/Gvg33.jpg, Retrieved 11/6/2014.

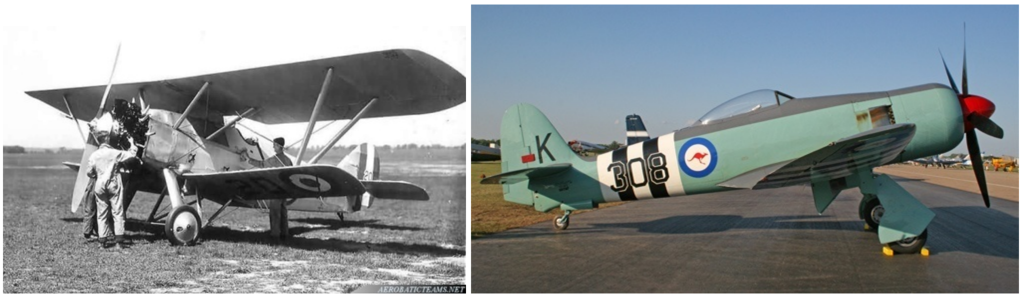

Figure 2.70 - British Siskin[92] and Sea Fury Airplanes[93].

With Soviet Union joining Germany attack, it was possible to Germany attack Poland from the west and the Soviet Union attacking Poland from the East. On September 17th, the Soviet Union forces reported that they have shot-down seven Polish fighters and three bombers. Germany on the west-side destroyed the city of Warsaw in spite of the city troops downing hundreds of German aircraft. Great-Britain and France forces were able to force Germany to retract towards the west, but Germany with over 1,500 fighter planes, plus its bombers, gliders, etc. caused Poland to surrender on October 5th. **Erro! A origem da referência não foi encontrada.** describe different airplane models built in Soviet Union on this WWII era and Figure 2.71 show the first and last airplane used by Soviet Union on this time of war.

Table 2.12 - Soviet-Union Airplanes in WWII. [83]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1929	Polikarpov Po-2 (Mule)	1941	Mikoyab-Gurevich MiG-1/MiG-3
1934	Polikarpov I-15 (Chaika)	1941	Petlyakov Pe-2
1935	Beriev Be-2 / MBR-2	1941	Petlyakov Pe-3
1935	Polikarpov I-16	1941	Sukhoi Su-2
1936	Tupolev SB-2	1942	Berezniak-Isayev BI
1937	Ilyushin IL-4	1942	Lavochkin La-5
1940	Petlyakov Pe-8 (TB-7)	1942	Tupolev Tu-2 (Bat)
1940	Sukhoi Su-1 / Su-3	1943	Yakovlev Yak-9 (Frank)
1940	Yakovlev Yak-1	1944	Lavochkin La-7
1941	Ilyushin IL-2 Sturmovik	1944	Yakovlev Yak-3
1941	Lavochkin LcGG-3		

[92] http://aerobaticteams.net/images/snowbirds/rcaf-siskins-02.jpg, Retrieved 11/6/2014.

[93] http://www.warbirdalley.com/images/SeaFury-N79SF-550.jpg, Retrieved 11/6/2014.

Figure 2.71 – Soviet Union Po-2 and Yak-3 airplanes.

In spite of winter in October 1939 and limited aerial operations due to weather conditions and low temperatures, Germany started air raids against England. Using their Vickers Wellington's bombers, the British Royal Air Force attacked designated cities in Germany trying to delay the opponents advance. France was busy defending their country borders with Germany using their Morane Saulnier MS.406's and American Hawk 75's at their service. Germany war reports gave their Messerschmitt Bf 110 fighters the upper-hand versus the British or the French air force airplanes.

The Soviet Union, while teaming up with Germany, invaded Finland late November 1939 using their Tupolev SB-2 bombers dropping incendiary bombs and explosives over the capital of Helsinki. In spite of losing 684 versus the 67 airplanes from Finland's Air Force, the Soviet Union Red Air Force won this so called "Winter War" and forced Finland to sign the Peace Treaty of Moscow in March 1940. Figure 2.72 reference Finland's airplane built in this WWII.

Figure 2.72 – Finland's 1943 VL Myrsky Storm airplane[94].

[94] http://www.militaryfactory.com/aircraft/imgs/vl-myrsky.jpg, Retrieved 11/6/2014.

In early May of 1940, Germany moved towards France. Strategically they went around the North-Western border of France, also known as the Maginot Line, by attacking their ground operations forcing the French to retreat giving Belgium no change other than to surrender in May 28th. Late May and early June, the British and French ground forces initiated retreat thru the English Channel while defended by the recent released British Spitfire airplanes which proved to be more maneuverable than the German Messerschmitt. German won the battle over Dunkirk, France but the British Air Force was able to help retreat over 330,000 men. Shortly after this conquer, Germany moves towards Paris taking control of that city and the entire French country in June 22th of 1940. Germany not only took control over the now called "occupied France" but used that countries work-force to produce military equipment including aircraft for the German troops.

Germany began the Battle of Britain under the code name "Sea Lion" by strategically attacking British supply lines followed by airfields and factories. The British Royal Air Force were able to defend and keep their grounds due to the Spitfire and Hurricane fighters' efficiency over the German fighters but that did not stop Germany which threw more fighters and bombers into battle in a two-to-one ratio. On September 1940, the British Royal Air Forces downed 56 German bombers which were dropping bombs during daylight in the cities of Great Britain. Due to this high loss the Germans decided to attack by night but they weren't aware of the recently developed British radar able to maintain their fighters in the ground until German bombers were close enough to attack. Germany shortly found out that they weren't able to destroy the Royal Air Force and in October 1940, they decided to postpone the invasion over Great Britain.

Although the United States agreed to be a neutral country they increased production of military goods, mainly to fulfill orders from France and Great Britain. They also started a Civilian Pilot Training Program that raised the number of troops with the final objective to help fight Germany without being drawn to war directly. Initially it all started on a cash-and-carry basis but shortly becoming a lease policy. As Britain required American-made airplanes but was running short on cash, both countries signed the Destroyers-Bases Agreement where the United States trade destroyers for 99-years leases on bases in the Caribbean and Newfoundland. Soon this so called neutral United States became an "Arsenal of democracy" by leasing all sorts of military equipment to Britain. This became the lend-Lease Act of 1941 allowing the United States to sell or lease supplies to those whose defense was key to their interest. Payments could come later in form of kind, property or in any accepted by the United States. During this war, the United States provided over 46 Billion Dollars on war supplies to the Allies which Great Britain was the number one "customer" with almost 32 Billion Dollars bill. **Erro! A origem da referência não foi encontrada.** and Figure 2.73 describe airplanes built in WWI and the first and last airplane used in WWII.

Trying to keep the United States out of the war, Germany decided to invade Soviet Union to strength Japan's power leaving Great Britain alone. On June 22nd 1941, Germany attacked Soviet Union from the Baltic Sea to the Black Sea on a ten-week program to gain control over them. Germany knew where Soviets airplanes, airfields and troops were due to reconnaissance flights before the invasion. Without any response why they were under attack, the Soviet Union decided to move aircraft factories to strategic locations. Soviet Union was at a major loss counting 2000 aircraft lost in two days. With winter approaching, the German became disoriented and out of focus giving Soviets time to the re-focus and re-group. Soon the Soviet Union was participating on the Lease Act and getting supplies from the United States with the intent to keep fighting Germany invasion (Bowman, 1997). and Figure 2.74 described American airplanes as well as first and last airplane used in this time of war.

Table 2.13 - Italy Airplanes in WWII. [83]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1934	Savoia-Marchetti SM.79 Sparviero	1938	Fiat G.50 Freccia (Arrow)
1935	Savoia-Marchetti SM.81 Pipistrello	1939	Fiat CR.42 Falco (Falcon)
1936	Breda Ba.65	1939	Macchi C.200 Saetta (Lightning)
1936	CANT Z.501 Gabbiano (Gull)	1940	Reggiane Re.2000 Falco I (Flacon I)
1936	CANT Z.506 Airone (Heron)	1941	Macchi C.202 Folgore (Thunderbolt)
1936	Caproni AP.1	1941	Reggiane Re.2001 Falco II (Flanco II)
1936	Fiat BR.20 Cicogna (Stork)	1941	Savoia-Marchetti SM.54
1937	Breda Ba.64	1942	Piaggio P.108
1938	CANT Z.1007 Alcione (Kingfisher)	1942	Reggiane Re.2002 Ariete (Ram)
1938	Caproni Ca.310 (Libeccio)	1943	Fiat G.55 Centauro (Centaur)
1938	Caproni-Campini N1 (CC.2)	1943	Macchi C.205 Veltro (Greyhound)
1938	Fiat CR.32		


Figure 2.73 - Italian SM.79[95] and C.205[96] airplanes.

Table 2.14 - US Airplanes in WWII. (Part I). [83]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1929	Boeing F4B / P-12	1942	Bell P-59 Aircomet
1929	Curtiss P-6 Hawk	1942	Curtiss SO3C Seamew
1932	Boeing P-26 Peashooter	1942	Curtiss-Wright C-46 Commando
1933	Curtiss A-12 (Shrike)	1942	Douglas C-54 Skymaster (DC-4)
1933	Stinson Reliant	1942	Douglas P-70 Nighthawk
1935	Curtiss SOC Seagull	1942	Grumman TBF Avenger
1935	Sikorsky S-43	1942	Lockheed PV-1 Ventura (Harpoon)
1936	Consolidated PBY Catalina	1942	Lockheed XP-49
1936	Douglas B-18 Bolo	1942	Republic P-47 Thunderbolt
1936	Douglas DC-3	1942	Sikorsky R-4
1936	Grumman J2F Duck	1942	Vought F4U Corsair
1936	North American T-6 Texan	1942	Vought V-173 (Flying Pancake)
1937	Boeing B-17 Flying Fortress	1942	Waco CG-4 (Hadrian)
1937	Boeing XB-15 (Grandpappy)	1943	Bell O-63 Kingcobra
1937	Brewster F2A Buffalo	1943	Boeing B-29 Superfortress
1937	Douglas TBD Devastator	1943	Brewster XA-32
1937	Grumman Goose (G-21)	1943	Consolidated PB4Y-2 Privateer
1937	Seversky P-35	1943	Curtiss-Wright XP-55 Ascender
1937	Vought SB2U Vindicator	1943	Curtiss-Wright XP-71
1938	Curtiss P-36 Hawk (Mohawk)	1943	Curtiss SB2C Helldriver
1938	Douglas SBD Dauntless	1943	Fisher XP-75 / P-75 Eagle
1939	Boeing 314 Clipper (C-98)	1943	Grumman F6F Hellcat
1939	Curtiss XP-42	1943	Hughes Model D-2 (XP-73 / XA-37)
1939	Curtiss-Wright CW-21 Demon	1943	Martin JRM Mars
1939	Lockheed P-38 Lightning	1943	McDonnell XP-67 Bat/Moonbat
1939	Vultee BT-13 Valiant	1943	North American B-25 Mitchell
1940	Beech AT-10 Wichita	1943	Northrop P-61 Widow

[95] http://upload.wikimedia.org/wikipedia/commons/9/9f/Two_Savoia-Marchetti_S.M.79_over_Sciacca.jpg, Retrieved 11/6/2014.

[96] http://upload.wikimedia.org/wikipedia/en/3/3a/C.205_V.JPG, Retrieved 11/6/2014.

Table 2.14 – US Airplanes in WWII. (Part II). [83]

Year	Manufacturer and Model	Year	Manufacturer and Model
1940	Bell XFL Airabonita	1943	Northrop XP-56 Black Bullet
1940	Bell XFM-1 Airacuda	1943	Northrop XP-79
1940	Consolidated PB2Y Coronado	1943	Vought XF5U (Flying Flapjack)
1940	Douglas C-47 Skytrain / Dakota	1943	Vultee XP-54 Swoose Goose
1940	Grumman F4F Wildcat	1944	Bell XP-77
1940	Martin Maryland (A-22)	1944	Consolidated Vultee TBY Sea Wolf
1940	North American P-51 Mustang	1944	Curtiss SC Seahawk
1940	Tucker XP-57	1944	Curtiss XF14C
1940	Vought OS2U Kingfisher	1944	Douglas A-26 / B-26 Invader
1941	Beechcraft XA-38 Grizzly	1944	Douglas BTD Destroyer
1941	Bell P-39 Airacobra	1944	Lockheed XP-58 Chain Lightning
1941	Boeing-Stearman Kaydet	1944	Republic XP-72 Super Thunderbolt
1941	Brewester XSBA-1 / SBN-1	1944	Vultee XA-41
1941	Consolidated B-24 Liberator	1945	Bell XP-83
1941	Curstiss P-40 Warhawk	1945	Consolidated B-32 Dominator
1941	Curtiss XP-46	1945	Douglas C-74 Globemaster
1941	Douglas A-20 Havoc/Boston	1945	Douglas DC-2
1941	Douglas A-24 Banshee	1945	Grumman F8F Bearcat
1941	Douglas XB-19 (XBLR-2)	1945	Hughes H-4 Hercules
1941	Grumman XP-50 Skyrocket	1945	Lockheed C-69 Constellation
1941	Martin B-26 Marauder	1945	Lockheed P-80 Shooting Star
1941	Martin Baltimore	1945	Ryan FR Fireball
1941	Martin PBM-3 / PBM-5 Mariner	1945	Vultee XP-81
1941	Northrop N-1M	1946	Hughes XR-11 / XF-11
1941	Northrop N-3PB Nomad	1946	Northrop YB-35
1941	Piper L-4 Grasshopper	1946	Republic XF-12 Rainbow
1941	Radioplane OQ-2	1948	Martin AM Mauler
1941	Vultee A-35 Vengeance		

On December 7th of 1941, Japan attacked the United States of America and British territories in the Pacific region. With 31 vessels, six of which were aircraft carriers with a total of 432 airplanes on board attacked Pearl Harbor, Hawaii without any warning. The United States had on their possession state-of-the-art radar in Hawaii but because it was new technology the warning was ignored by surveillance troops thinking the airplanes were American (Latham & Stobbs, 1996). That same day, war was declared to Japan. Due to the fact that Japan had signed military alliances with Germany and Italy in September 1940, the United States were now directly involved in Europe (Francillon, 1987). Figure 2.75 shows Japanese airplanes: first and last used in WWII.

As it was expected, war brought the need to continuous research and development, not only to create new aircraft designs but everything within them. From avionics, to engines, not missing guns and bombs were a focus throughout the world. Germany started the helicopter idea in 1930's but only in 1940 the Focke-Achegelis Fa223 became mass-produced.

Table 2.15 - Japan Airplanes in WWII. [83]

Year	*Manufacturer and Model*	*Year*	*Manufacturer and Model*
1936	Mitsubishi G3M Rikko (Nell)	1942	Nakajima Ki-43 Hayabusa (Oscar)
1937	Mitsubishi A5M (Claude)	1942	Yokosuka D4Y Suisei (Judy)
1937	MitsubishiKi-15 (Babs)	1943	Kawanishi N1K-J Shiden (George)
1937	Nakajima Ki-27 (Nate)	1943	Kawasaki Ki-61 Hien (Tony)
1938	Kawanishi H6K (Mavis)	1943	Kawasaki Ki-64 (Rob)
1938	Mitsubishi Ki-30 (Ann)	1943	Kawasaki Ki-96
1939	Mitsubishi Ki-21 (Sally)	1944	Aichi B7A Ryusei (Grace)
1940	Aichi D3A (Val)	1944	Aichi E16A Zuiun (Paul)
1940	Kawasaki Ki-48 Sokei (Lily)	1944	Kawasaki Ki-102 (Randy)
1940	Mitsubishi A6M Rei-sen (Zero)	1944	Kawasaki Ki-45 KAlc Toryu (Nick)
1940	Mitsubishi Ki-67 Hiryu (Peggy)	1944	Mitsubishi Ki-109
1941	Aichi E13A (Jake)	1944	Nakajima Ki-84 Hayate (Frank)
1941	Kawasaki Ki-60	1945	Aichi M6A Seiran
1941	Mitsubishi G4M (Betty)	1945	Kawasaki Ki-100
1941	Mitsubishi Ki-46 (Dinah)	1945	Kyushu J7W Shinden
1941	Nakajima B5N (Kate)	1945	Kyushu Q1W Tokai (Lorna)
1941	Nakajima Ki-44 Shoki (Tojo)	1945	Mitsubishi A7M Reppu (Sam)
1941	Nakajima Ki-49 Donryu (Helen)	1945	Mitsubishi J8M (Shusui)
1942	Kawanishi H8K (Emily)	1945	Nakajima G8N Renzan (Rita)
1942	Kawasaki Ki-45 Toryu (Nick)	1945	Nakajima J9Y Kikka
1942	Kyushu K11W Shiragiku	1945	Nakajima Ki-115 Tsurugi
1942	Mitsubishi J2M Raiden (Jack)	1945	Yokosuka MXY7-K1 Ohka
1942	Nakajima B6N Tenzan (Jill)	1946	Nakajima Ki-201 Karyu
1942	Nakajima J1N Gekkou (Irving)		

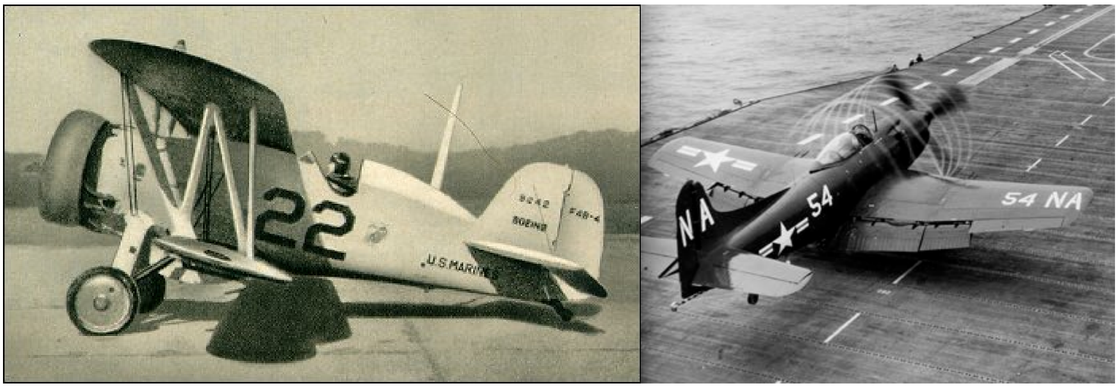

Figure 2.74 – US P-12[97] and Mauler[98] airplanes.

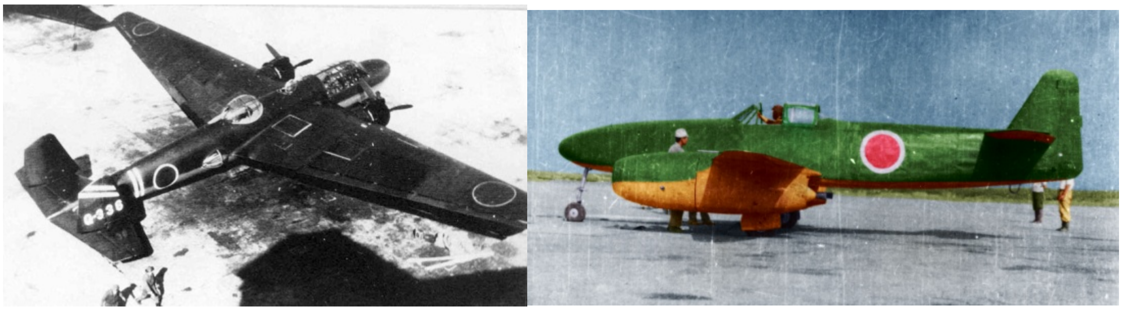

Figure 2.75 – Japanese G3M[99] and Ki-201[100] airplanes.

Jet engines were invented by Frank Whittle from Great Britain and Hans von Ohain from Germany. Great-Britain's first jet flight took place in March 1943 and Germany's first jet flight was in July 1942. Due to the fact that these two countries are in war with each other, Great Britain transferred their jet technology to the Unites States. General Electric was the company selected to copy the Whittle jet engine (Constant II, 1980).

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[97] http://www.aviastar.org/pictures/usa/boeing_p-12.jpg, Retrieved 11/6/2014.

[98] http://upload.wikimedia.org/wikipedia/commons/2/27/AM-1Q_VC-4_USS_Kearsarge_1949.jpg, Retrieved 11/6/2014.

[99] http://www.militaryfactory.com/aircraft/imgs/mitsubishi-g3m-nell.jpg, Retrieved 11/6/2014.

[100] http://img805.imageshack.us/img805/3679/result82a.png, Retrieved 11/6/2014.

Figure 2.76- Airplane availability at start of WWI.[101]

The United States as stated previously, created the cash-and-carry and the Lend-Lease agreement with its Allies. This agreement was crucial to the United States economy and the idea of increasing factories, the number of workers and equipment was not enough for the demand. Aviation companies transformed their single job-shop to line production factories changing production and management methods improving the output dramatically. Using Henry Ford's idea on the automobile industry, the US aircraft manufacturers started to use their factories on a similar manner. Assembly equipment became aligned in sequence with special equipment designed and developed to support manufacturing demand. The assembly line was the location where all sub-components would gather to complete these units (aircrafts). Components were broken into sub-assemblies brining work-centers and specialized people to focus on certain items only. Engineering and the manufacturing floor worked closely developing detailed procedures, drawings, templates like jigs and fixtures and part specifications always ensuring quality on the work floor. Women played a big role in the United States manufacturing capabilities. They received training or were hired with training. Women initiated trade school just like men and after training was complete they worked as machine operators, stock chasers, laboratory technicians, draftsmen, engineer and clerks.

Table 2.16, Table 2.17, and Figure 2.77 to Figure 2.81 show airplanes of remaining countries involved in this war.

[101] http://en.wikipedia.org/wiki/Focke-Achgelis_Fa_223#mediaviewer/File:Fa_223_im_Hubschraubermuseum_B%C3%BCckeburg.jpg; Retrieved 9/28/2014.

Table 2.16 - Netherlands Airplanes in WWII. [83]

Year	*Manufacturer and Model*
1938	Fokker D.XXI
1938	Fokker G.I (Reaper)
1938	Fokker T.V
1938	Koolhoven F.K.56
1939	Fokker T.IX
1940	Koolhoven F.K.58

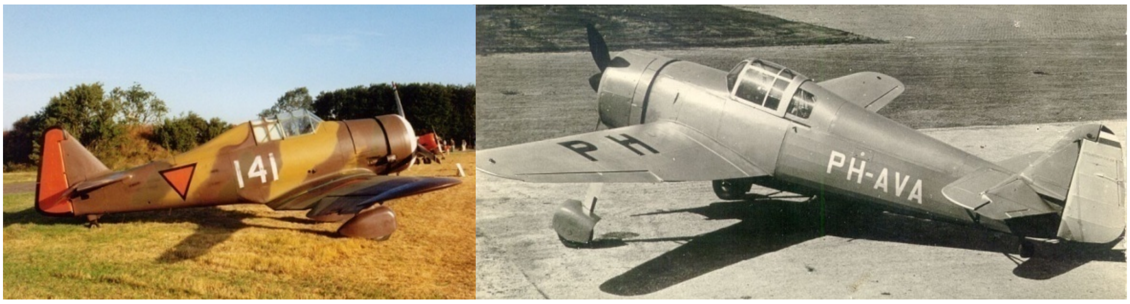

Figure 2.77 - Netherland D.XXI[102] and F.K.58[103] airplanes.

Table 2.17 - Czech Airplanes in WWII. [104]

Year	*Manufacturer and Model*
1921	Aero A.11
1934	Ava B.534
1937	Aero A.304

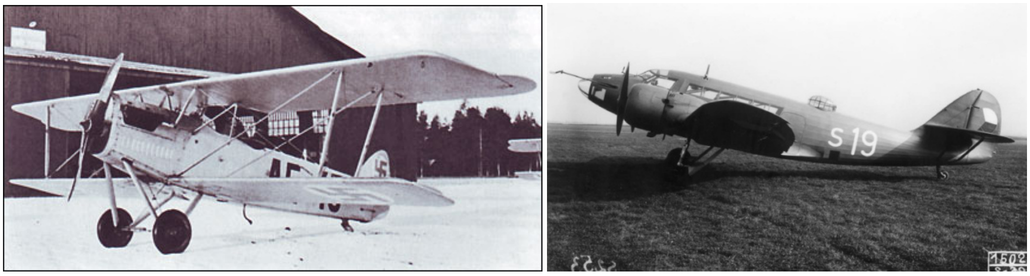

Figure 2.78 - Czech A.11[105] and A.304[106] airplanes.

[102] http://www.militaryaviation.eu/images/Fokker/D-XXI_141.jpg, Retrieved 11/6/2014.

[103] http://www.alexdenouden.nl/artikelen/afbeeldingen/FK58.jpg, Retrieved 11/6/2014.

[104] http://www.militaryfactory.com/aircraft/ww2-aircraft.asp ; Retrieved 9/28/2014.

[105] http://www.aviastar.org/pictures/czech/aero_a-11.jpg, Retrieved 11/6/2014.

[106] http://files.brannamoc1938garda.webnode.cz/200000657-93513944be/Aero%20A-304%20c.jpg; Retrieved 11/6/2014.

Figure 2.79 – Romainian 1941 IAR / IAR 81 airplane[107].

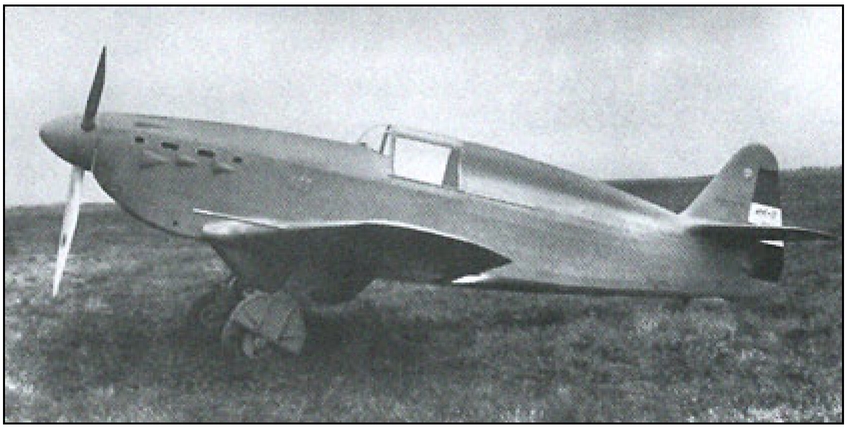

Figure 2.80 – Yugoslavia 1940 Rogozarski IK-3 airplane[108].

Figure 2.81 – Sweden 1945 Saab J21 RB Airplane[109].

Figure 2.82 is very important to this study as it will show the importance of air power being established in early stages. Countries like the US and Germany provided an amazing boost in technology pushing the flying envelope always further. The

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[107] http://www.ipmsstockholm.org/magazine/2005/03/images/iar80_09.jpg; Retrieved 11/6/2014.

[108] http://www.aviastar.org/pictures/yugoslavia/rogozarski_ik-3.jpg; Retrieved 11/6/2014.

[109] http://planesandchoppers.com.s3.amazonaws.com/4866.jpg, Retrieved 11/6/2014.

availability to build new airplanes from fighters to bombers, from single engines to jets, from single passengers to cargo airplanes set a precedent and this is noticeable until nowadays.

On May 7th, 1945 Germany surrendered and shortly after on August 14th, 1945 Japan surrendered as well. The war was over and troops were allowed to go back home.

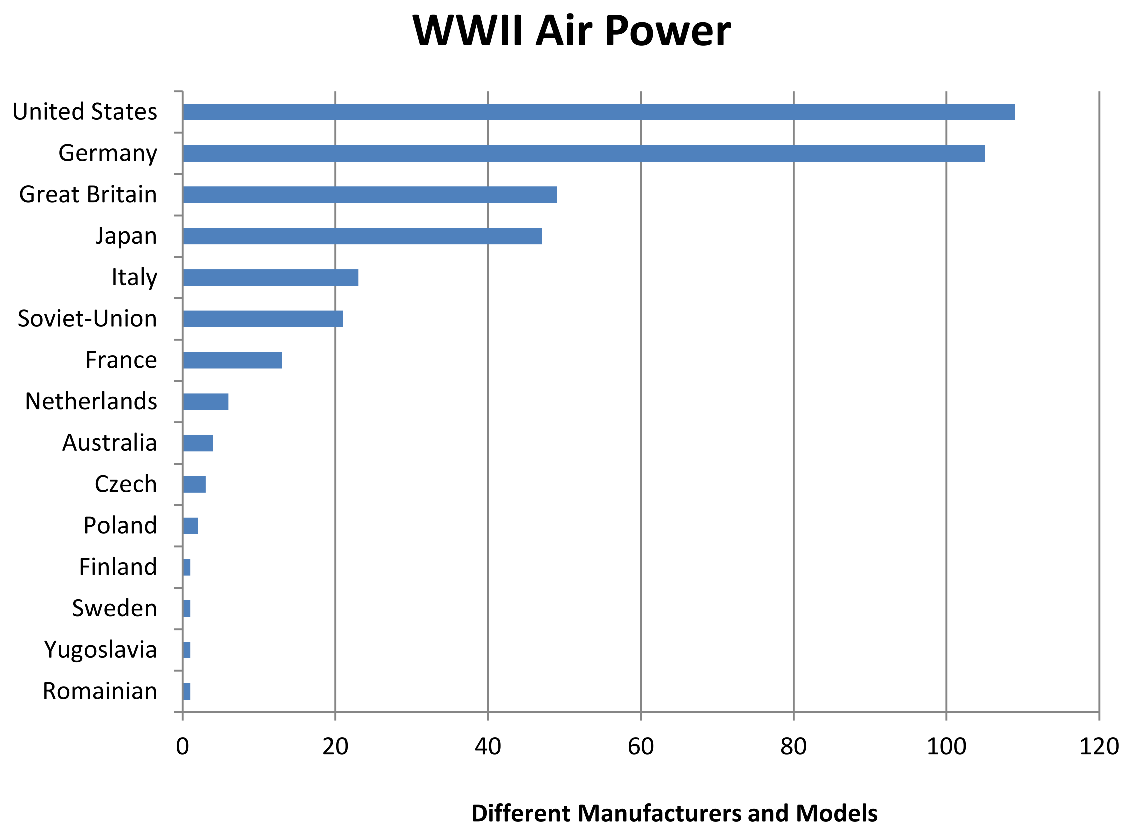

Figure 2.82 - Airplane availability in WWII.

Between 1957 and 1989 the so called Race to the Moon ear was seen as an exploration, an adventure, a scientific and technological challenge but mostly as a political statement. Although various countries "competed" to achieve the outer space, it was the United States of America and Soviet Union that set pace trying to show to the world who was more advanced and had more knowledge. Political parties from both countries thought that with outer-space rockets and satellites, the opposing country could spy on each other anywhere on Earth and these could become tools to dominate space. In 1958, US Senator Lyndon Johnson stated that "Control of space means control of the world" – this might have been an overstatement but nonetheless capture American society interest to support this technological challenge (Salkeld, 1970).

On October 4th 1957, Soviet Union announced to the world that they had launched the first artificial satellite into orbit around Earth using an intercontinental missile. This satellite was called "Sputnik" which can be translated to "Moon companion" or "Fellow traveler". Sputnik inspired both world powers to speed-up the construction of missiles, massive-destruction weapons and space programs.

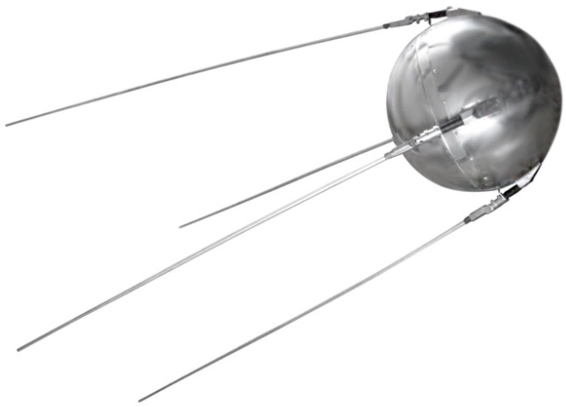

Figure 2.83 – Soviet Union's Sputnik[110].

Figure 2.84 – US Vanguard Satellite[111].

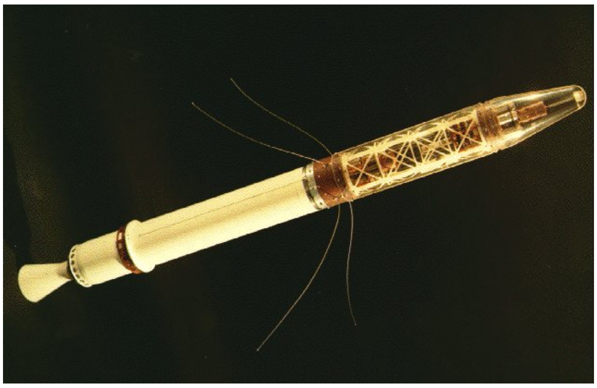

Figure 2.85 – US Explorer rocket/satellite[112].

[110] http://www.maxuta.com/maxuta/collections/032_pn_space_collectibles/032044_first_sputnik_model_01.jpg; Retrieved 11/19/2014.

[111] http://upload.wikimedia.org/wikipedia/commons/thumb/7/7f/Vanguard_1.jpg/260px-Vanguard_1.jpg; Retrieved 11/20/2014.

At this point they still believed that control of outer-space would mean control over the world. Soviet Union in 1957 launched Sputnik 1 and Sputnik 2 which this later one carried a small dog named Laika. In 1958 the Soviet's launched Sputnik 3 and the United States launched several satellites. American satellites didn't have a great success with five failed Vanguard's and two out of five Explorer's never made to orbit.The United States shortly after launched their own satellites and formed in 1958 the military Advanced Research Projects Agency (ARPA) where it unified federal agencies, universities and industry. At this point the well-known NASA – National Aeronautics and Space Administration took over US projects. Roger D. Launius stated "NASA's projects were clearly cold war propaganda weapons that national leaders wanted to use to sway world opinion about the relative merits of democracy versus communism of the Soviet Union" – once more proved the political statement behind this era. The Soviet Union created a similar program replacing military personnel for space technicians, engineers and scientist – they changed philosophies from the conventional military forces to missiles and nuclear missiles.

Figure 2.86 – Original 1958 NASA Symbol[113].

In 1958 the US Department of Defense using previous scientific discoveries in 1946 from John D. DeWitt, Jr. was able to communicate between Washington and Hawaii using radio waves bouncing off the Moon surface. This was just the beginning of long-range transmissions as in mid 1960 it was possible to have a phone conversation using Echo1 satellite and later that year the ability to record messages and

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[112] http://upload.wikimedia.org/wikipedia/commons/7/73/Explorer1.jpg; Retrieved 11/20/2014.

[113] http://www.nasa.gov/images/content/256357main_Symbols1-xltn.jpg; Retrieved 11/20/2014.

broadcasting them back to Earth. In 1962 using Relay1 satellite (Figure 2.87) the US was able to provide television broadcast worldwide (Martin, 2000).

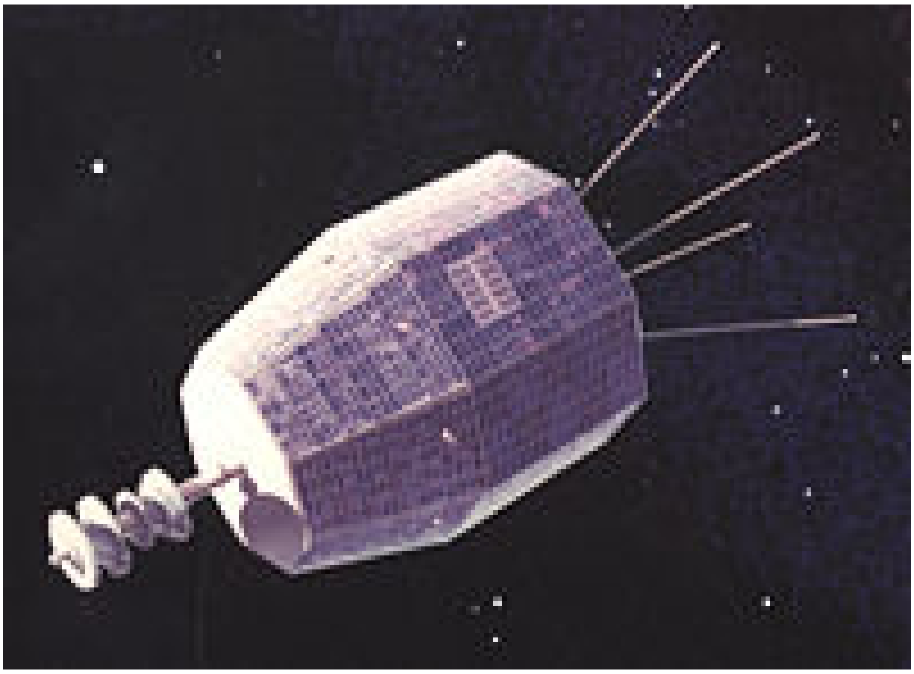

Figure 2.87 – US Relay 1 Satellite. (Martin, 2000)

Intelsat was founded in 1964 by the United States and eleven other countries and in 1971 Soviet Union responded with the Intersputnik trying to break Intelsat's international control. China was able to launch their first satellite in 1984 with features like telephone, telegraph and data communication. As part of this competition to the moon, there was also interest in missions to Mars using Soviet's Mars satellites between 1971 and 1973 and US Viking's Satellites in 1975; but also interest in missions to Venus using Venera's and Vega's satellites between 1961 and 1984 while the US sent Pioneer Venus satellites in 1978.

After all probes, satellites and animals (dogs and monkeys), the Soviet Union was the first country to put a man, a female, a space crew and able to navigate outside the satellite in space. However, it was the United States of America in July 20th of 1969 with the Apollo project that successfully placed Neil Armstrong on the Moon surface allowing him to set foot and explore Moon's surface (Figure 2.88). A total of 12 astronauts walked on the Moon from that historical date to April 1972 and since then, none has been to the Moon ever since.

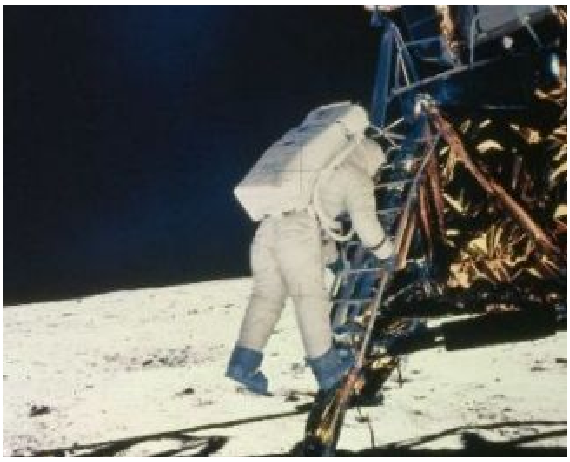

Figure 2.88 – Neil Armstrong first step on the Moon.[114]

2.2. Ethical and Social Aspects of Aerospace Engineering

A particularity of the Aerospace Engineering is the priority to safety issues due to the unquestionable catastrophic consequences that a reckless attitude can cause. So, a large part of the ethical and social aspects are foreseen in a quite complete legislation. In 1903, eight countries joined a convention held in Berlin, Germany initially named International Commission for Air Navigation (ICAN) but no decision on rules was reached. The second attempt also in Berlin, in 1906 included 27 countries but same result. It wasn't until 1912 that under the 3rd convention held in London, the first set of rules regarding call signs for aircraft usage came to fruition.

In December 7th 1944 in Chicago, 52 countries gathered for another convention and established the Provisional International Civil Aviation Organization (PICAO). PICAO started its operations on June 6th, 1945 and upon majority this organization became ICAO (International Civil Aviation Organization, Figure 2.89). This non-provisional organization started in April 4th, 1947 and is still active to this day. ICAO is now linked to the United Nations Economic and Social Council (ECOSOC) and its main focus is to standardize air navigation (principles and techniques) as well as the development of international air transport focusing on safety and growth.

In spite of ICAO's rules, there are two main agencies in charge or regulating civil aviation. These authorities are the FAA (Federal Aviation Administration, Figure 2.90) and the JAA (Joint Aviation Authorities, Figure 2.91). FAA has authority on American ground and the JAA over European matters.

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[114] http://www.kidport.com/reflib/science/moonlanding/Images/MoonLanding.jpg; Retrieved 11/20/2014.

Figure 2.89 – ICAO's logo[115].

FAA was formed in August 23rd of 1958 and operates under federal government while linked to the US Department of Transportation. The FAA is currently divided into four "sections":

- Airports [ARP] – this section regulates and verifies compliance to federal rules in all matters regarding airports construction and their operations[116];
- Air Traffic Organizations [ATO] – this section manage nationwide commercial air traffic coming in and out of the US plus all civil aviation[117];
- Aviation Safety [AVS] – this section is in charge of pilots, airlines and its crew certifications as well as aircraft airworthiness[118];
- Commercial Space Transportation [AST] – this section is in charge of protecting US assets during launch or re-entry of commercial space equipment[119].

Figure 2.90 – FAA logo[120].

115 http://www.icao.int/Pages/default.aspx; Retrieved 11/26/2014.

116 http://www.faa.gov/about/office_org/headquarters_offices/arp/; Retrieved 11/27/2014.

117 117 http://www.faa.gov/about/office_org/headquarters_offices/ato/; Retrieved 11/27/2014.

118 http://www.faa.gov/about/office_org/headquarters_offices/avs/; Retrieved 11/27/2014.

119 http://www.faa.gov/about/office_org/headquarters_offices/ast/; Retrieved 11/27/2014.

120 http://upload.wikimedia.org/wikipedia/commons/thumb/d/de/US-FederalAviationAdmin-Seal.svg/2000px-US-FederalAviationAdmin-Seal.svg.png; Retrieved 11/27/2014.

As stated above, the JAA is similar to the FAA agency however operating in Europe (non-EU and EU members). JAA was formed in 1970 and by then the main gold was to standardize the certification for larger airplanes and their engines to meet European industry and international venues. Only later in 1987, the JAA started to define standards and issue certificates for aircraft operations, maintenance and licenses (airplanes, pilots and crew members). JAA has been since 2002 incorporated into a larger organization also known as EASA [European Aviation Safety Agency].[121]

Figure 2.91 – JAA logo[122].

These two last reviewed agencies, seem to operate and regulate aviation while only being separated by the Atlantic Ocean. As every member of aviation knows, in anything related to aviation, you have to be compliant to rules from the FAR's books [Federal Aviation Regulations (FAA related)] or the JAR's books [Joint Aviation Regulations (JAA related)]. These books contain chapters and sub-chapters regulating airports, operations, crew, mechanics, inspections, etc. Although these books operate similarly, there are some differences mainly on the licensing sections. Once a civil pilot is recognized with a FAA license under part 61 and 141 of the FAR book, that pilot certificate is valid worldwide however a civil pilot holding a JAA license under JAR-FCL [Flight Crew License] can only fly within JAA member states (which exclude Albania, Armenia, Azerbaijan, Montenegro, Serbia and Ukraine). Depending on the authority in questions, the civilian pilot is required to keep current with flight time and medical check-ups differently. Both FAA and JAA have commercial pilot certificates programs that are similar and compliant with ICAO's rules allowing EU or US pilots to operate commercial airplanes worldwide. The biggest difference between FAA and JAA is regarding mechanic operations. JAA requires more training time for a mechanic license when compared to FAA

[121] http://en.wikipedia.org/wiki/Joint_Aviation_Authorities; Retrieved 11/27/2014.

[122] https://jaato.com/cms/image/jaaseal-white-strt.jpg; Retrieved 11/27/2014.

requirements. JAA requires in-field training time while FAA does not. Different onions can be formed upon that last statement but the truth to the matter is that it works – the US safety record of US carriers which monitor their own maintenance is a proved factor of reliability. In the other hand, JAA mechanics are more centrally controlled for that type and model of aircraft or engine.

As we can foresee, these differences between authorities takes a big toll on all pilots and all crew members, not only on their jobs but their life. As this thesis will show on the next section, this interaction and differences between different countries have a direct impact on people's lives.

Airplanes and airliners are now a common industry throughout the world and the need to regulate, maintain and promote safety, are and will always be closely monitored, requiring labor workforce.

Nevertheless, not all the ethical and social aspects are covered by the legislation, and their existence still gives a certain degree of freedom to the operators and employees. Additionally, the Philosophy and Ethics of Aerospace Engineering involves other aspects that exceed the professional ethics or an "ethical code" such as: a conceptual analysis of right and wrong, good and bad, in engineering practice; an understanding of the ethical dimensions of engineering; to pursue interdisciplinary, cooperative research into professional ethics codes, disciplinary procedures, moral educational strategies, and more.

Chapter 3. Results

3.1. Methodology

3.1.1. Framework

As shown on the previous chapter, the ability to fly became of extreme importance for all nations, not only on the defense field but as a mean of transportation and leisure as well – transportation of people, merchandise, mail, etc.; and leisure for those with the dream of flying. Who in early 1900's thought we would have the possibility to travel across the globe in a few hours? Who thought about the possibility of buying silk clothes and have it next day delivered to your house? All of this became possible due to aeronautical knowledge, due to the development of better, faster, safer airplanes and due to the ability of some societies to embrace this as a mean to grow economically. We all know there are other means of transportation like automobiles, trains, boats, but I believe we all agree that the airplane will always be the faster means of transportation.

The war has reviewed in the previous chapter has been the major factor causing this aeronautical development due to the fact that some countries have the capital necessary to push the envelope further and try new things. Although the war is pushing the technology always ahead of the curve, passengers and cargo airplane manufacturers have been crucial for the aeronautical development as well. Nowadays, we have the possibility of transporting 300 plus passengers across the globe in hours or have heavy machinery (cars, airplanes, industrial equipment, etc.) readily available. An example of such an airplane is shown in Figure 3.1: the Antonov 225. Of course there is a cost for this means of transportation but sometimes it makes sense when compared to the other only mean of transportation (by sea) taking 1-2 months before it arrives its final location. Although only some companies are able to carry super-heavy loads, most airlines not only carry people but goods between different locations.[123]

Throughout time two major airplane manufacturers showed the world their technology while building their airplanes with state of the art designs and equipment. Airbus and Boeing have been in competition since the day they were formed and they have been "pushing the envelope" while trying to convince their

[123] http://www.antonov.com/aircraft/transport-aircraft; Retrieved 11/4/2015.

customers that their airplanes are better and more efficient than the other. These two companies are in different sides of the world and therefore Airbus has an advantage on the European side as Boeing has advantage on the North America side. Another company, much smaller than the ones previously referred operating on the South America side of the world is Embraer. This company although smaller has a good nitch on the market on smaller airplanes and on the maintenance industry. Because these three companies, Airbus, Boeing and Embraer, are located in different parts of the world, allowing them to distribute their ultimate goods to the different customers throughout the world, they were chosen to be studied and ultimately compared on this thesis.

Figure 3.1 – Antonov 225.[124]

Airbus – The European Airliner

Airbus (Figure 3.2) was founded in December 1970 with headquarters in Blagnac, France near Toulouse and currently contains production lines in France, Germany, Spain and the United Kingdom[125]. Airbus manages 16 different sites in these four countries mentioned above plus a joint-venture in Tainjin, China and has subsidiaries in the United States, Japan and India[126].

[124] https://www.aircraft-info.net/wp-content/uploads/2014/05/an-255-cargo-door-open.jpg; Retrieved 11/4/2015.

[125] http://www.airbus.com/company/aircraft-manufacture/how-is-an-aircraft-built/production/; Retrieved 1/22/2016.

[126] http://www.airbus.com/presscentre/pressreleases/press-release-detail/detail/first-airbus-final-assembly-line-outside-europe-inaugurated-in-tianjin-china/; Retrieved 1/22/2016.

Figure 3.2 - Airbus Logo.[127]

Airbus Industries was defined by the France, Germany and UK governments with initial goal was to compete with the American companies like the one described in the next chapter. As these governments began the discussion to create this company able to produce mass civilian aircrafts, they began in 1967 with the idea of developing the first A300, a 320 seat twin-jet airliner (Royal Aero Club, 1997). France was in charge of manufacturing the cockpit, flight-control systems and lower fuselage, England was in charge of the wings, Germany in charge of the forward, rear and center fuselage as well as the flaps and spoilers and later on Spain in charge of the horizontal stabilizers.[128] Rolls-Royce (a UK Company) would manufacture the jet engines known as the RB207 but due to previous commitments to a US company (Lockheed Martin), difficulties on R&D phases and the release delays, forced Airbus to reconsider the 320 seater changing their business plan to the A300B which would become a 250 seater using Rolls-Royce existing jet engines (Endres, 2004).[129] The A300 Series took maiden flight in 1972 and a couple of years later the A300B2 come into service.[130] In 1978 airbus launched the A310, a more advance aircraft in comparison with the A300B2 (Figure 3.3), which grant them 256 orders of this new A300 Series aircraft.[131] However, it was until 1987 with the launch of the well-known A320 and over 400 orders (before its maiden flight that Airbus was defined as a major manufacturer in the aircraft industry.[132]

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[127] http://www.airbus.com/presscentre/corporate-information/logo-downloads: Retrieved 1/22/2016.

[128] http://www.airbus.com/company/history/the-narrative/early-days-1967-1969/; Retrieved 1/22/2016.

[129] pp. 45.

[130] Watkins, Harold (26 August 1974). "Selling Airbus to U.S. carriers a tough task". *Los Angeles Times.*

[131] http://news.bbc.co.uk/2/hi/business/802741.stm; Retrieved 1/22/2016.

[132] Belden, Tom (22 August 1982). "Airbus takes flight with big-jet sales". Philadelphia Inquirer.

Figure 3.3 – Airbus A300B2, Farnborough show in 1974.[133]

In spite of the A320 orders, the Airbus team continued to research further to compete on the high capacity segment with the Boeing 747 released by the Americans in early 1970 (Norris & Wagner, 2005)[134]. The main idea presented at the Farnborough Air Show in 1990 was to modify the single-aisle A300 Series to a double-decker providing more passengers and reducing 15-20% in operating costs while compared to the Boeing 747-400 (Norris & Wagner, 2005)[135]. Due to several technological delays, it wasn't until 17 years later that the Airbus 380 was released for service for a 7-hour transatlantic trip from Singapore to Sydney.[136] Due to the global economy, Airbus was forced to re-structure in 2007 by releasing some facilities and ultimately some of them were sold to other sub-contractors.[137]

In December 2010, Airbus announced the A320neo "New Engine Option" and a few months late while at the Paris Air Show, Airbus booked US$72 Billion worth of orders from 16 different customers[138]. Airbus has recently joined developing efforts with a

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[133] https://en.wikipedia.org/wiki/Airbus_A300#/media/File:Air_France_Airbus_A300B2_1974_Fitzgerald.jpg ; Retrieved 1/22/2016.

[134] pp.7.

[135] pp.16-17.

[136] http://news.bbc.co.uk/2/hi/asia-pacific/7061164.stm; Retrieved 2/8/2016.

[137] http://news.bbc.co.uk/2/hi/business/6402859.stm; Retrieved 2/8/2016.

[138] http://www.airbus.com/presscentre/pressreleases/press-release-detail/detail/airbus-with-new-order-record-at-paris-air-show-2011/; Retrieved 2/8/2016.

company called Aerion[139] (Figure 3.4) to develop the first fleet customer business jet names AS2 able to reach Mach 1.6 [140] – the first flight is intended to happen in 2019 and submit for certification in 2011[141].

Figure 3.4 – Aerion AS2 Supersonic Business Jet.[142]

Boeing – North American Airlines

Boeing (Figure 3.5) headquarters is located in Chicago, Illinois (USA) and it was founded in 1916 by William Boeing. Boeing is currently the biggest global aircraft manufacturer in the world with 159,469 employees[143] and positive revenue of $96.1B (US Dollars)[144].

Figure 3.5 – Boeing Logo.[145]

Boeing is currently divided into five divisions – Boeing Commercial Airplanes; Boeing Defense, Space & Security; Engineering, Operations & technology; Boeing Capital; and Boeing Shared Services Group[146].

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139 http://www.aviationtoday.com/the-checklist/Airbus-and-Aerion-Collaborate-to-Develop-Supersonic-Business-Jet-High-Performance-Flight_83090.html#.VvKCOVUrLIU; Retrieved 3/23/2016.

140 http://www.aerionsupersonic.com/speed/; Retrieved 3/23/2016.

141 http://aviationweek.com/business-aviation/airbus-help-aerion-design-supersonic-business-jet; Retrieved 3/23/2016.

142 http://www.aerionsupersonic.com/; Retrieved 3/23/2016.

143 http://www.boeing.com/company/general-info/; Retrieved 3/28/2016.

144 https://www.google.com/finance?q=NYSE%3ABA&fstype=ii&ei=zifHVvngJs2XmAHYxbiwAw; Retrieved 3/28/2016.

145 http://www.boeing.com/company/key-orgs/advertising-and-brand/index.page#/logo-trademarks-copyrights; Retrieved 3/28/2016.

William E. Boeing started this empire by purchasing a shipyard on the Duwamish River in Seattle on March 1910 and officially registered the place as Pacific Aero products Co[147]. With the help of Navy Lt. Conrad Westervelt and Donald W. Douglas, a MIT prodigy, they flew the first B&W airplane on June 15th, 1916 (Figure 3.6). Using Boeing's experience in the timber industry and wooden structures they built this particular seaplane with 52 feet wingspan, 27ft 6 inches long weighing 2,800 lbs. – later on they improved this seaplane with "better pontoons and a more powerful engine"[148].

Figure 3.6 – B&W (Boeing Seaplane).[149]

William Boeing decides to rename his company to "Boeing Airplane Company" on May 9th, 1917. Later that year, World War I started for the Unites Stated and Boeing sent two Model C's seaplanes to be used by the Navy which in returned ordered 50 more. With the end of WWI in November 11th 1918, Boeing redirects his focus to commercial airplanes for transport of people and goods (including mail). On December 27th of 1919, the B-1 Boeing Airplane makes its first flight able to carry the pilot, two passengers and mail[150]. A few months later, Boeing makes its first flight with Boeing Model 8 airplane, a 2 passenger biplane winning another world records on flying over

146 http://www.boeing.com/company/#/key-organizations; Retrieved 3/28/2016.

147 https://web.archive.org/web/20141017044937/http://www.boeing.com/boeing/history/chronology/chron01.page; Retrieved 4/17/2016.

148 https://web.archive.org/web/20141129081141/http://www.boeing.com/boeing/history/boeing/bw.page; Retrieved 4/17/2016.

149 https://web.archive.org/web/20141017044137/http://www.boeing.com/boeing/history/narrative/n004boe.page; Retrieved 4/18/2016.

150 https://web.archive.org/web/20141017044137/http://www.boeing.com/boeing/history/narrative/n004boe.page; Retrieved 4/18/2016.

Mount Rainer, Washington at 14,411 feet altitude[151,152]. On 1923 Boeing tried to win a race against Curtiss on the design and development of a fighter for the US Army Air Service but he lost that contract – Boeing continued to manufacture the PW-9 fighter witch later gave birth to the well-known P-12/F4B fighter leading their company to the biggest fighter manufacturer.

In 2006, Boeing started to look into low-cost and environmental friendly airplanes. This would result on various concept designs with open rotors for lower cruising speed; thin and long wings with the ability to fold for taxiing and storage; forward swept wings with the intent of diminishing engine noise; and a delta wing design with the ability to carry hundreds of passengers[153]. Boeing has also filed a patent on a fore field technology but they are yet to confirm this as a viable option and perform necessary tests[154].

South American Airlines

Embraer (Figure 3.7) headquarters is located in São Paulo, Brazil and it was founded in 1969 by the Brazilian government while trying to develop a domestic aircraft industry[155]. Although Embraer is a much smaller company then the ones mentioned above, they employee over nineteen thousand people[156] and a positive revenue of $5.7B (US Dollars)[157].

Embraer currently has offices in 12 offices in Brazil, 6 in the US, 2 in China, 2 in Portugal, 1 in France, Ireland, Netherlands, Singapore, the United Arab Emirates and

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151 http://www.peakbagger.com/peak.aspx?pid=2296; Retrieved 4/18/2016.

152 https://web.archive.org/web/20140904130137/http://www.boeing.com/boeing/history/chronology/chron02.page; retrieved 4/18/2016.

153 Dominic Gates (May 18, 2006). "Clean engines, wings that fold: Boeing dreams of futuristic jets". *The Seattle Times.*

154 Hernandez, Vittorio (31 March 2015). "Boeing Gets Patent For Force Field Technology That Protects Vehicles From Nearby Blasts". *International Business Times*; Retrieved 31 March 2015.

155 "Timeline", *Historical Center* (official site), BR, Embraer; Retrieved 11/4/2015.

156 http://ri.embraer.com.br/show.aspx?idCanal=y+WJJM+h6a4PAt2D3JKl1w==&linguagem=en; Retrieved 11/4/2015.

157 http://www.forbes.com/companies/embraer/; Retrieved 11/4/2015.

the United Kingdom[158]. Figure 3.8 shows the different office locations throughout the world.

Figure 3.7 – Embraer Logo.[159]

Figure 3.8 – Embraer Offices in the World Map.[160]

This Brazilian manufacturer produces military, commercial, executive and agricultural airplanes while offering aeronautical services providing maintenance and repairs to those in need[161]. It wasn't until 1975 that Embraer expanded their customer base further than for the domestic use[162]. Embraer produced their first turboprop passenger airplane, the Embraer EMB 110 Bandeirante in 1973 and by 1985

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158 http://www.embraer.com/en-US/ConhecaEmbraer/PresencaGlobal/Pages/default.aspx; Retrieved 11/4/2015.

159 http://www.embraer.com/en-US/Pages/home.aspx; Retrieved 11/4/2015.

160 http://www.embraer.com/en-US/ConhecaEmbraer/EmbraerNumeros/Pages/Home.aspx; Retrieved 11/5/2015.

161 https://en.wikipedia.org/wiki/Embraer; Retrieved 11/4/2015.

162 http://www.centrohistoricoembraer.com.br/en-US/HistoriaEmbraer/Pages/Historico.aspx; Retrieved 11/4/2015.

they entered the export market within the smaller airliners with the EMB 120 Brasilia[163].

Figure 3.9 - Embraer EMB 110 Bandeirante.[164]

Figure 3.10 - Embraer EMB 120 Brasilia.[165]

As Embraer had the services available to perform maintenance and repairs in various aircrafts, Piper, a well-known North American company, joined Embraer in 1974 to assemble kits provided by this US Company to support Brazil and Latin America markets. Embraer built close to 2,500 airplanes between 1974 and 2000 for the US manufacturer[161]. Although Embraer was sold to private owners on December 7th of 1994, the Brazilian movement still maintains a fair amount of precious shares allowing them to control this growing industry and its fate (Anuatti-Neto, Barossi-Filho, Carvalho, & Macedo, 2005). With the intent of growing and expanding, Embraer slightly changed their manufacturing focus into the small commercial airplanes in mid 1990's and soon expanded that side of the business to larger regional aircrafts and smaller jets (Monks & Minow, 2011). In 2007, Embraer announced the idea of developing a larger twin-jet for the military transportation able to carry up to 23Tons of cargo but we haven't yet seen this airplane[166].

Up to this date Embraer has developed more than 850 business jets, more than 50 military aircrafts and over 5000 commercial aircrafts have been delivered throughout

[163] http://epocanegocios.globo.com/Informacao/Visao/noticia/2012/12/ozires-silva.html; Retrieved 11/4/2015.

[164] https://en.wikipedia.org/wiki/Embraer_EMB_110_Bandeirante#/media/File:VHKGQ.JPG; Retrieved 1/14/2016.

[165] http://barrieaircraft.com/images/embraer-emb120-brasilia-02.jpg; Retrieved 1/14/2016.

[166] http://www.embraerdefensesystems.com/english/content/cargo/performance.asp; Retrieved 11/4/2015.

the world making them the 3rd biggest commercial jet manufacturer[167]. Trying to get a piece of the action on the long range aircrafts, Embraer released plans to develop a new jet in 2010 and three years later announced the Lineage 1000E (Figure 3.11). Shortly after a recent airline names Air Costa, originally from India, ordered 50 aircrafts reflecting a $2.94B value[168].

Figure 3.11 - Embraer Lineage 1000E.[169]

3.1.2. Data, Variables and Hypothesis

The general company data such as number of employees, aircraft deliveries, number of employees, and revenue were obtained from aircraft manufacturer's official publications.

The salary details could not be obtained from direct inquiry, because it was found to be impracticable. So, the selected source was the Glassdoor database which holds more than 8 million company reviews and data supplied anonymously by employees. Within the Glassdoor database, the Airbus company records show 595 employee reviews and 1200 salary details; the Boeing company records show 4200 employee reviews and 5700 salary details Embraer records show 146 employee reviews and 184 salary details.

Accordingly, the variables are the Company (Airbus, Boeing, and Embraer), Number of Employees, Yearly Revenue, and Country of Work (USA, EU).

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[167] http://www.embraer.com/en-US/ConhecaEmbraer/EmbraerNumeros/Pages/Home.aspx; Retrieved 11/5/2015.

[168] http://articles.economictimes.indiatimes.com/2014-02-14/news/47306277_1_lepl-group-air-costa-ramesh-lingamaneni; Retrieved 11/4/2015.

[169] https://upload.wikimedia.org/wikipedia/commons/0/0d/Embraer_ERJ-190-100ECJ_Lineage_1000_-_Ryabtsev.jpg; Retrieved 1/14/2016.

The next section will present and analyze some economic data in terms of world impact as well as the relevant social aspects. The hypothesis of the present work is based on the following question: the salaries follow the Company revenue?

3.2. Airplane Manufacturers and Industry Comparison

Although both companies, Airbus and Boeing can almost be compared side-by-side, Embraer cannot due to its size and due to the fact that it is government based as mentioned above. Airbus and Boeing have been competing since the 90's[170].

Airbus and Boeing have developed similar airplanes for the transport market segment like the single aisle A319/A320 (Airbus) versus the 737 (Boeing), the double-aisle A330/A350 (Airbus) versus the 777/787 (Boeing) and the double-deck A380 (Airbus) versus the 747-8 (Boeing). Single-aisle Airbus airplanes from the 140 to 206 passenger average around $110.5M while Boeing's airplanes from the 126 to 178 passengers average around $105.6M – a difference of $4.9M. Double-aisle Airbus airplanes from the 257 to 366 passengers average around $295.24M while Boeing's airplanes from the 242 to 425 passengers average around $313.26M – a difference of $18.02M. Double-deck Airbus airplanes able to transport 544 passengers are listed at $428M while Boeing's airplane able to carry 410 passengers is listed at $378.5M – although Boeing's double-deck airplane is to compete with the Airbus A380 we can't help to notice a 134 passenger difference which "justify" the Airbus $49.5M extra cost[171,172].

A big portion of the price difference mentioned on the paragraph above, yet unknown due to the logistics on the viability of who's buying what from whom, is on the outsourcing, the long business relationships and the technology available on the different programs (engines, flight controls, structures, etc.)[173,174]. At this point, we would assume that a European airliner will tend to choose a European airplane while the North-America airliners will choose a local airplane, correct? Not quite! As Figure 3.12 shows, Boeing only loses track of a world monopoly on sales in the Latin-

[170] Airlines Industry Profile: United States, Datamonitor, November 2008, pp. 13-14.

[171] "Airbus Family Figures MARCH 2016"; Retrieved from the Airbus Website on April 2016.

[172] http://www.boeing.com/commercial/737max; Retrieved 4/29/2016.

[173] *Gates, Dominic (March 1, 2010). "Albaugh: Boeing's 'first preference' is to build planes in Puget Sound region". The Seattle Times; Retrieved 4/29/2016.*

[174] "Airbus' China gamble". *Flight International*. October 28, 2008; Retrieved 4/29/2016.

American market. Boeing is winning the European market with 59% versus 41% from Airbus and 83% versus 17% from Airbus on the North-American market.

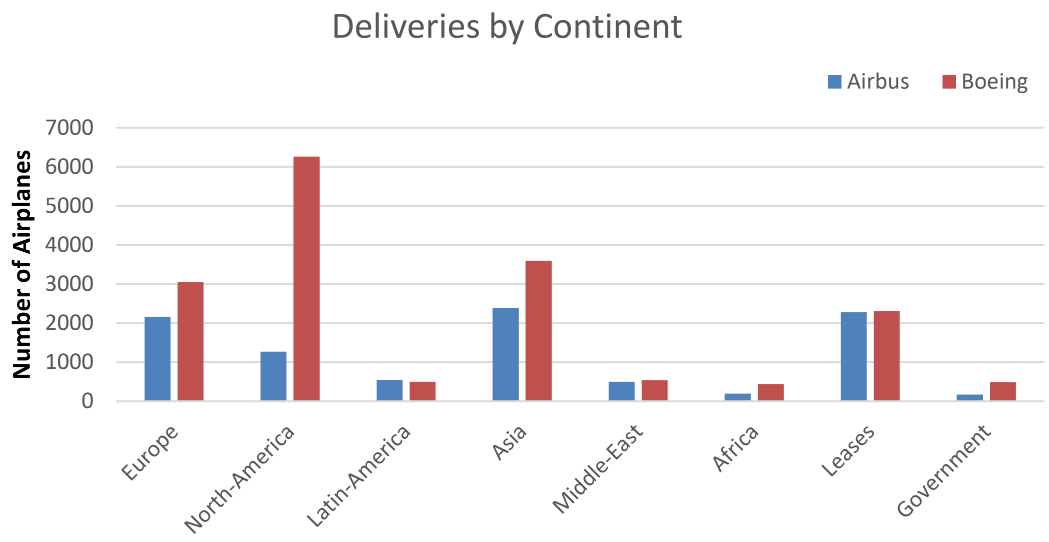

Figure 3.12 – Airbus and Boeing's Airplane Deliveries per Continent.[175,176]

One very important fact affecting the world's economy was the recent crisis between 2007 and 2009. Due to the fact that one airplane takes months, if not years to build, some of the orders were placed in previous years and then delivered as soon as possible.

As Figure 3.13 and Figure 3.14 show, Boeing came to the economic crash years with a substantial higher number or airplane orders but it was Airbus that maintain higher order volumes until now as long as we disqualify the year 2012 and the present year (due to reports unavailability).

Please note that both companies keep growing. It is visible that Boeing has been able to deliver more airplanes since 2012 until nowadays but as Figure 3.15 shows the number of employees working for Boeing is almost double than its competitor (Airbus).

[175] http://www.boeing.com/commercial/#/orders-deliveries; Retrieved 4/29/2016.

[176] http://www.airbus.com/company/market/orders-deliveries/; Retrieved 4/29/2016.

Figure 3.13 – Airbus and Boeing's Airplane Order Comparison. [175,176]

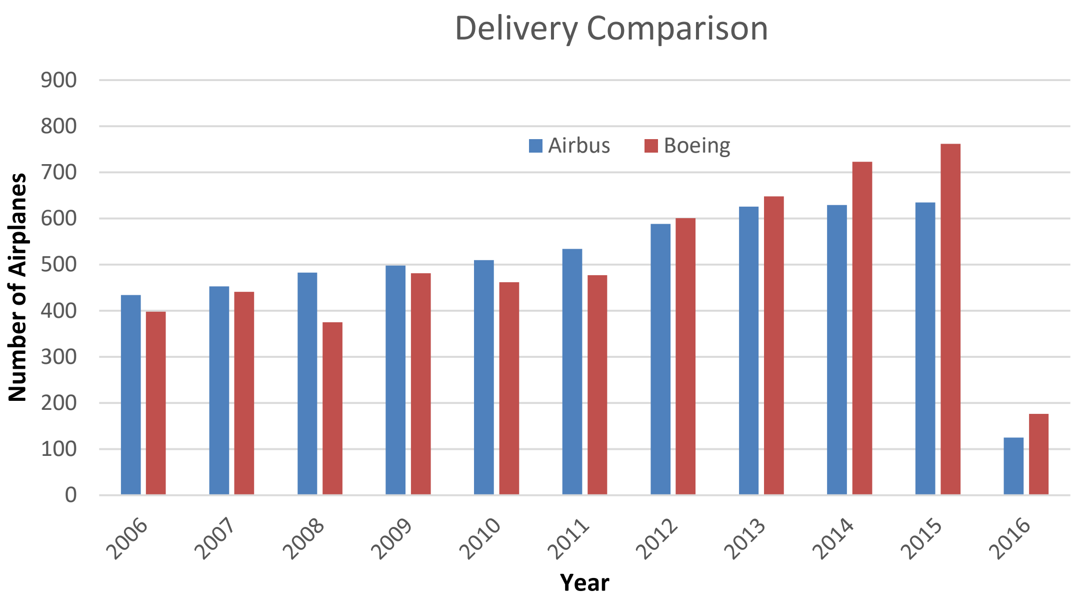

Figure 3.14 – Airbus and Boeing's Airplane Deliveries Comparison. [175,176]

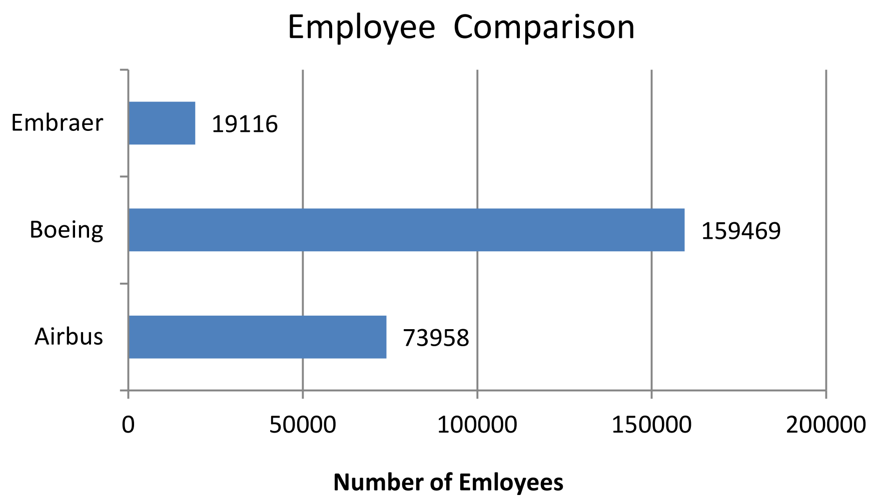

Figure 3.15 - 2015 Airbus, Boeing and Embraer's Employee Comparison.[177, 178, 161]

Figure 3.16 shows all three companies reported revenues in 2015 supporting Boeing's deliveries and employee numbers.

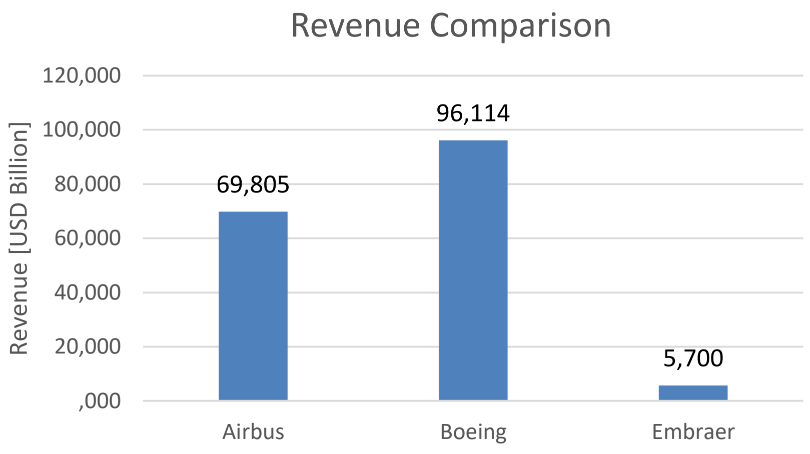

Figure 3.16 - 2015 Airbus, Boeing and Embraer's Revenue Comparison.[177,178,161]

3.3. Engineer Salaries Analysis

The following salary comparison values shown below correspond to data recorded throughout time by those working on that particular company and position. This data is being used for comparison purposes only due to the fact that other important factors like the date of that reported data was recorded cannot be accounted for.

[177] https://en.wikipedia.org/wiki/Airbus, Retrieved 5/21/2016.

[178] https://en.wikipedia.org/wiki/Boeing, Retrieved 5/21/2016.

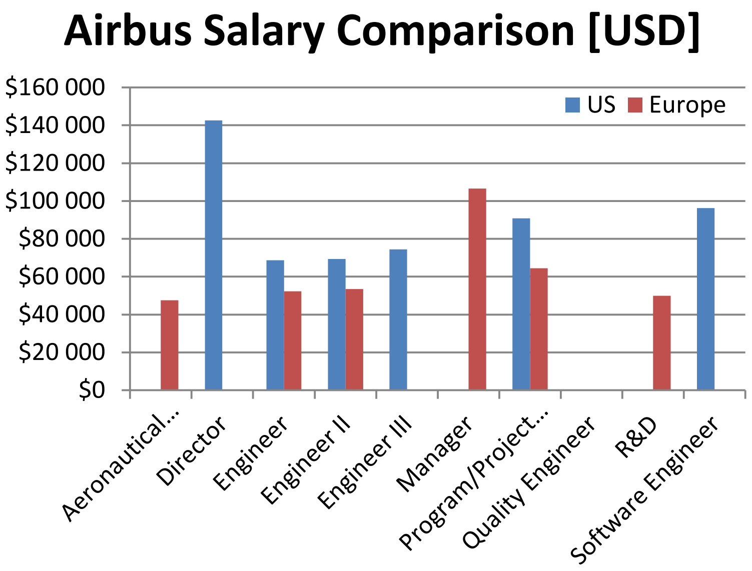

Figure 3.17 – Airbus Reported Salaries in Europe and USA.[179]

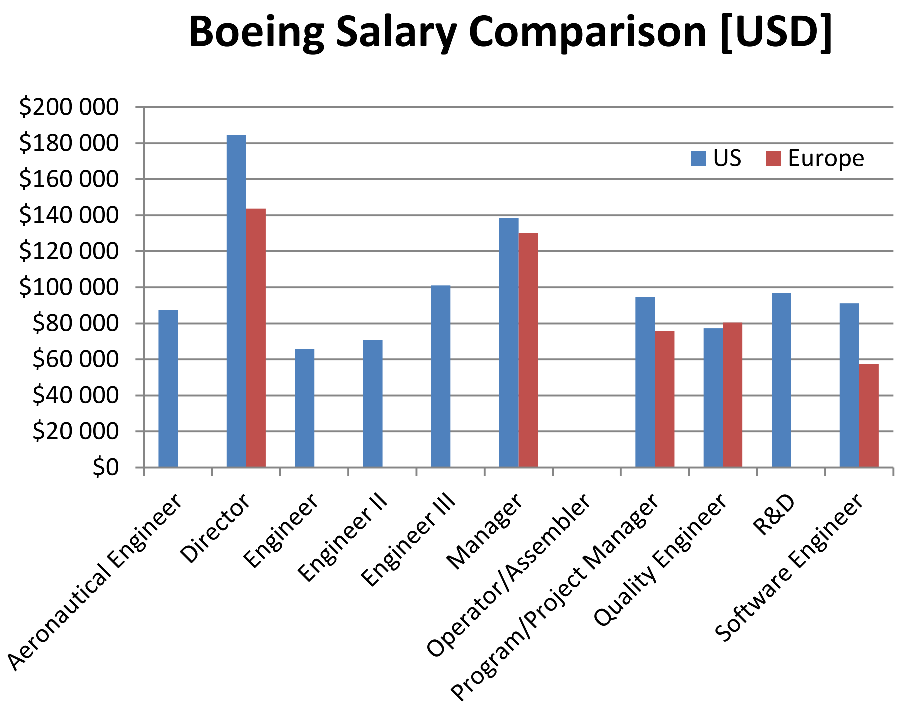

Figure 3.18 – Boeing's Reported Salaries in Europe and USA.[179]

[179] https://www.glassdoor.com/Salary/, Retrieved 5/21/2016.

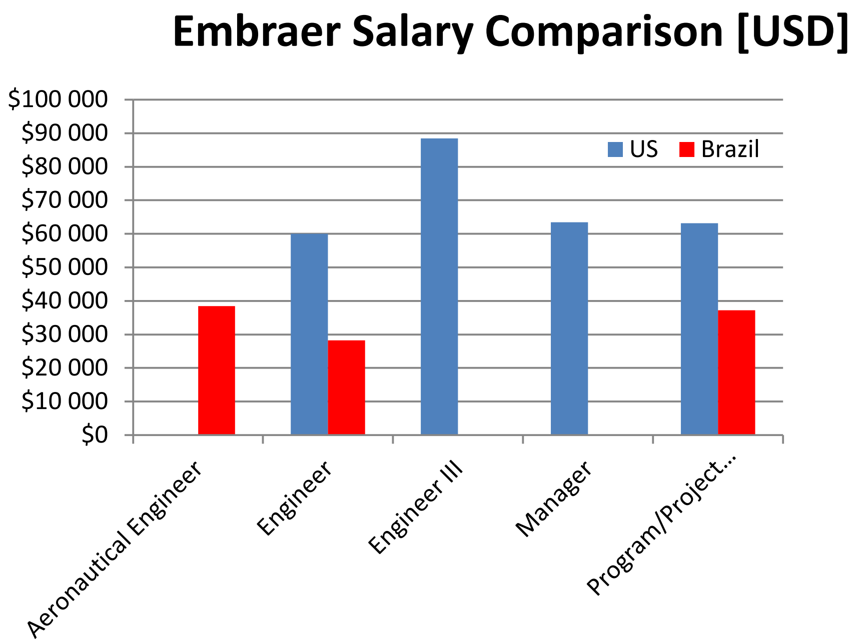

Figure 3.19 - Embraer Reported Salaries in Brazil and USA.[179]

By comparing data from graphics from Figure 3.17, Figure 3.18 and Figure 3.19, it is visible that the same Manager makes over $20K per year if they would be working in Europe for Boeing instead of Airbus and $75K more if they would be working in the US for Boeing instead of Embraer.

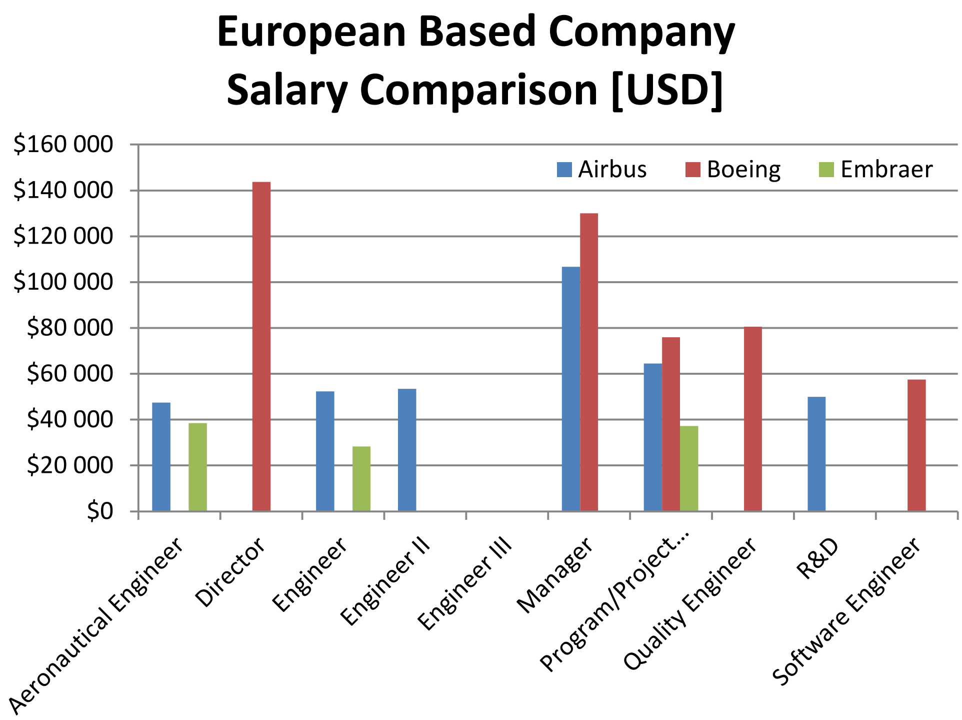

Figure 3.20 - European Salary Comparison.[179]

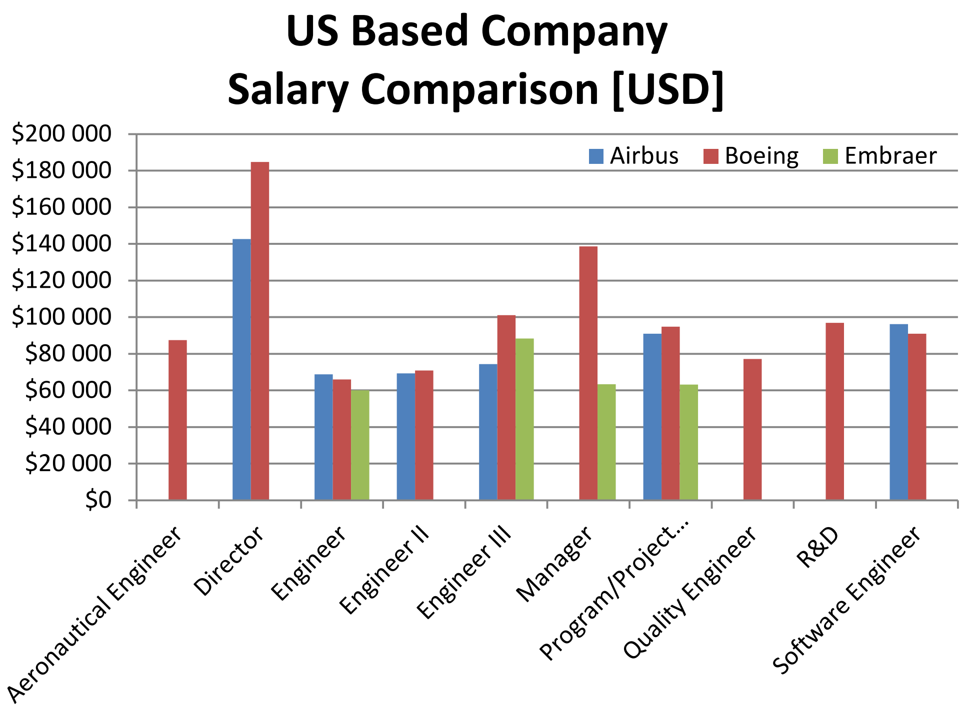

Figure 3.21 – USA Salary Comparison.[179]

Chapter 4. Conclusions

4.1. Summary of the Thesis

This thesis presented the link between the aerospace/aeronautical engineering and world-wide economy growth (or lack of it!). This was done by analyzing the salaries of the airplane industry in the United States, France and Brazil, and their relation to the company income and country.

Chapter 2 described the motivation and scope of the Philosophy and Ethics of Engineering, including the historical evolution and the particularities of the Aerospace Engineering.

Chapter 3 discusses the methodology used, and presents the general economic indicators of each aircraft manufacturer such as number of employees, aircraft deliveries, number of employees, and revenue as well as the salaries per company and country.

4.2. Discussion

4.2.1. Contribution of this Thesis

This thesis has shown that the idea that a European airliner will tend to choose a European airplane while the North-America airliners will choose a local airplane is not valid. Boeing only loses track of a world monopoly on sales in the Latin-American market, but it is winning the European market and the North-American market.

Various points of discrepancy between Airbus, Boeing and Embraer have been found. A particular relevance is attributed to amount of money shared with the employee, if by salary, bonus etc. is directly related to the persons, and their families, lifestyle. It should be noticed that U.S. dollar amount reported per company is reviewed by that country finance department and although there are various sub-companies internally like the military divisions, they all report to the corporate. Economic factors like cost-of-living can be questionable when reviewing numbers like the ones posted above, but that does not explain why the same appliances, electronics, vehicles, etc. are five to ten times more expensive in Europe than in the USA. The only thing that might be considered cheaper (in some places) in Europe is food and housing. Brazilian economy and lifestyle cannot be included on the same bracket as

Europe and USA due to the fact that the company reviewed for this study, Embraer, is substantially supported by the Brazilian government. Although Airbus and Boeing are partially subsidized by their correspondent government on their military divisions, they are still required to post earnings for taxes purposes.

Airbus has a ratio of $943.8K per employee, Boeing with $602.7K and Embraer with $298.2K. How can we explain that if a company like Airbus that has a $300K ratio per employee bigger than its immediate competitor (Boeing), then why the comparable manager makes $20K less per year than if they were working for Boeing? Various dollar amount differences can be found for all other positions from the base pay of a start-up engineer around $10K to a director around $40K extra. Furthermore, if we isolate the manager, which pay-scale is normally between a limited range across the company, and as posted that same manager makes $107K per year (gross) working for Airbus while the same individual can earn $129K (per year) working for Boeing while living and working in Europe, then how can we explain the $22,000 difference? Using a similar approach, that same manager makes $63K per year working for Embraer while the same individual can earn $138K (per year) working for Boeing while living and working in the US – how can we explain the $75,000 difference? If we identify the same engineers that graduated in the same university and one left to work for Boeing in the US and the other one for Airbus in Europe, the probability of that engineer being able to provide for himself and his family are much higher to the one that immigrated.

Recently with the economic crash between 2007 to 2009, all airplane manufacturers noticed their sales decline but rapidly gain momentum to keep growing and although all companies have been reaching best revenues results ever, we don't see that impact being directly translated into the employee and ultimately towards society in Europe or Brazil. The price of airplanes increases every year due to inflation to support increased cost of living but that doesn't seem to be helping the individual worker(s).

After all the research done throughout this thesis we are of the opinion that greed, power, lobbyism, politics and corruption are the factors behind this discrepancy! To continue to formulate a conclusion, let us review the meaning of each of these words:

- Greed – "Intense and selfish desire for something, especially wealth, power or food."
- Power – "The capacity or ability to direct or influence the behavior of other or the course of events."
- Lobbyism – "A person that tries to influence legislation on behalf of a special interest."
- Politics – "The activities associated with the governance of a country…"
- Corruption – "Dishonest or fraudulent conduct by those on power, typically involving bribery."

If philosophy "is the study of general or individual problems related to reality, existence, knowledge, values, reason, mind and language" and ethics is when a rational argument becomes a matter or right or wrong, we can then conclude that these definitions don't match at all. The reasoning behind the numbers posted above, mainly on the revenue to employee ratio, shows that there is no reasoning to support the difference between individual salaries which will ultimately reflect on their lifestyle and ability to support their family needs. Although we are concluding this on the individual manner, it is fairly simple to increase on the exponential form when it becomes bigger in size and we think of society. How can someone think about others without being able to support the needs of their own family?

4.2.2. Limitations of the Current Work

The salary data cannot be confirmed individually, but there is some confidence on it due to the control access to the Glassdoor database. Since there is no correlation with the date of the inquiry it is not possible to perform an analysis using constant prices.

4.3. Future Work

Further research needs to be done to understand government impact on the company (ies) profit sharing and maybe that will bring insight to this huge discrepancy between companies, countries, economics and politics.

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