

THE CONTRIBUTION OF DIFFERENT COUNTRIES TO AIRPLANE DEVELOPMENT AND MANUFACTURE- PART I. INVENTION OF AIRPLANE

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In the beginning of the 20th century the airplane stopped being a fancy, but became a reality. Uncontrolled “jumpers” were replaced by vehicles capable of long flights and maneuvering in the air.

The airplane was created by efforts of dozens of enthusiasts from different countries. It is truly an international invention.

Even in high antiquity people realized that wings were required for flying. That idea, which originated as a result of watching birds, can be traced to legends and mythology of numerous nations.

Eventually, men felt a strong desire to realize this dream of flying. The way to achieve that seemed evident: one should create artificial wings resembling those of birds, attach them to the arms and imitating the flapping movement of the birds wings, rise off the ground. The materials for wing manufacturing such as sticks, straps, feathers were available to an ancient man, and attempts to fly “like a bird” were made, apparently, even before the Common Era.

But practice and researchers' conclusions proved the impossibility of flight using man-powered artificial wings, and while there are 14 known attempts at this in 1580–1679, in the following hundred years only 7 attempts to “fly like a bird” were made.

The “classical” ornithopter concept crisis led to the idea of using a fixed surface such as a parachute or a kite along with a moving one. That allowed slowing the airplane descent and reduce the energy required for flight. This innovation was the most important moment in the airplane concept development.

First mention of an airplane with a fixed wing and propellers can be found in the studies by a Dutch engineer and scientist H. Huygens.

A drawing in his hand, dated approximately 1689, depicts in essence an airplane model with propellers driven by twisted animal sinews [1].

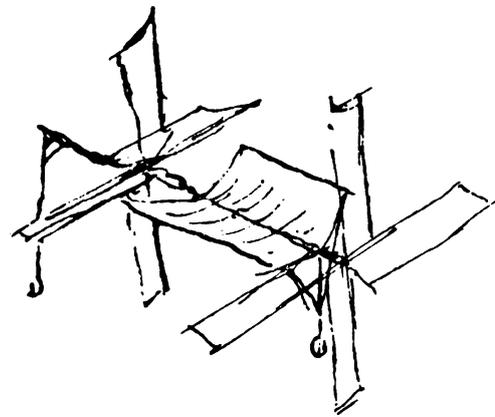


Fig. 1. A model by H. Huygens had all the components of an airplane: wing, engine, propellers

The first person to seriously address the matter of flying a heavier than air craft and raise the issue to a new level was the British scientist G. Cayley. Unlike his predecessors and numerous enthusiasts who worked after him, Cayley did not limit himself to designing the outside appearance of the airplane, he set the goal of determining its main parameters (power, wing load, position of the center of gravity) based on scientific experiment. He was the first to conduct experiments measuring the force created by the wing depending on speed and attack angle. The scientist performed these experiments in 1804 using the so called rotary machine, which allowed measuring the lift power of an aerodynamic surface rotating around the axis of the testing unit.

In order to validate the experimental data and study the flight stability issues, Cayley conducted experiments using a flying glider model. When thrown up into the air, the model would fly 18-27 m.

The results of Cayley's research, published in a scientific magazine [2], could stimulate further development of airplane-related studies, and hasten the emergence of this type of airplane. But that did not happen. The researcher's ideas fell onto unprepared soil and did not bear immediate fruit. Even in the most advanced industrial country of the 19th century — England — the idea of a heavier-than-air flying machine was considered utopian. So the article “On aerial navigation” did not attract any interest from the contemporaries and remained unnoticed. The first airplane engineering designs appeared only three decades later.

In 1842 an Englishman W. Henson registered as an invention patent “Air steamer”. The design contained all main components of an airplane: wing, controlled tail fins, fuselage, landing gear, engine and propellers.

Henson's airplane design became the best known amongst the aviation-related projects of the 19th century. Unlike Cayley publications, it immediately became widely popular: the airplane drawings were published in *Illustrated London News*, *Illustration* magazines and other large-circulation publications of the time, as well as the first studies on aviation history. It became motivation for many aviation pioneers, among them the creator of the first Russian plane A.F. Mozhaysky.

After developing an airplane design, an inventor would, naturally, want to bring his idea to life. Shipbuilding and furniture building experience allowed creating complex shaped structures and good mechanical properties of certain wood types provided light weight. For supporting the wing and other parts of an airplane, calibrated wire used to make musical instruments could be employed. Therefore, the technology level allowed building the planes.

However, the heavy weight engines prevented bringing these project to life for a long time: in the mid-19th century the best steam engine prototypes — the only power unit of the time — weighed about 50 kg/hp. All attempts to use muscle strength for flying were, of course, unsuccessful.

The atmosphere of misunderstanding and ridicule that often surrounded the aviation pioneers' work would also have a significant

effect. “We are regarded as people who would desire to, for instance, build a railroad to the Moon or something of that sort”, wrote A.V. Evald, who was Russia's first engineer to take interest in aviation engineering [3].

The possibility of creating a heavier-than-air airplane with a fixed wing was denied not only by people who were strangers to science, but also by many leading scientists — Helmholtz, Navier, Gay-Lussac. They appealed to the conclusion drawn from the impact theory of environmental resistance, developed by Newton. According to this theory, the wing lift is proportional to sine of an attack angle between the supporting surface and ram airstream, squared; and therefore, at low attack angles of 3° - 10° , characteristic for flight, it's very insignificant. Another argument by the opponents of dynamic flight was the so called “square-cube” rule, according to which the mass of an object increases noticeably faster than its linear dimensions. Therefore, in some scientist's opinion, even if heavier-than-air machines could possibly fly, it would only be small scale models.

In addition, airplane engineering was a costly and risky enterprise. Few were ready to sacrifice a large amount of money for the sake of an improbable idea of building a manned heavier-than-air airplane. In 1843 W. Henson tried to establish a joint stock company in England in order to finance the plane of his design, but as a result, he was just ridiculed. For a long time after that the airplane inventors would limit themselves to describing their ideas on paper or, in the best case scenario, building models.

The first to risk everything: capital, career, reputation to create an airplane were Navy officers F. du Temple in France and Alexander Mozhaysky in Russia, who built first full-size airplanes with steam engines. Both aircraft were unable to fly.

In the late 19th century in France one more attempt in creating a steam-powered airplane named *Eole* was made. It was made by a well-known engineer and inventor C. Ader. Ader did not do any scientific research or model building, but instead decided to recreate a natural prototype — a bat — as close as possible. It is

difficult to explain why he, a talented engineer himself, chose a design method so odd for the late 19th century, ignoring the scientific approach to airplane design that was typical for many aviation pioneers, including his compatriots F. Nadar, A. Penaud, F. du Temple.

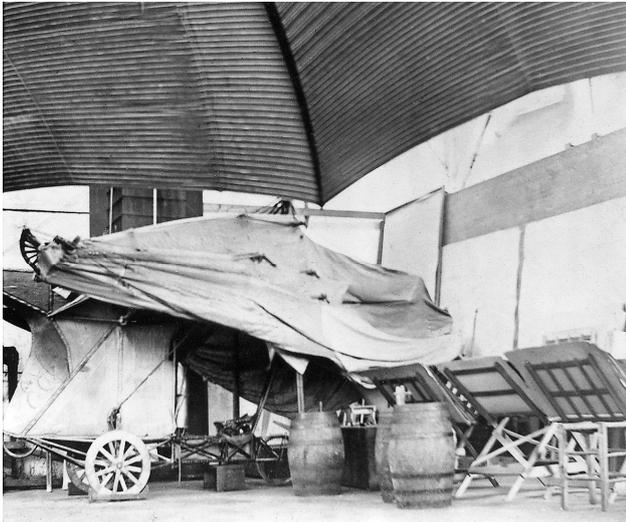


Fig. 2. Inside Clement Ader's workshop. This is the only surviving photograph of *Eole* (wing folded). In the foreground is the second Ader's airplane *Avion-3* wing

The most advanced part of *Eole* was its engine. Ader managed to create a steam engine with relative weight of only about 3 kg/hp, including the weight of boiler and condenser. A 20 hp engine with compound stage expansion had two cylinders. It was manufactured from forged steel, and in order to decrease the weight to a maximum degree everything that could be made hollow, was hollow. The watertube boiler was heated by alcohol; the air-cooled condenser was located under the fuselage. Due to high weight excellence of the power unit and lightweight structure of the airplane frame, power load in *Eole* was 14.8 kg/hp, which is 4–5 times less than that of the airplanes designed by du Temple and Mozhaysky.

In 1890 during tests Ader's airplane became airborne after a takeoff run and remained in the air “cutting close to the surface” (that is, rising slightly) for several seconds. Of course, this result cannot be called a flight; considering the lack of stability and control in *Eole*, no lengthy flight was possible at all. Built in 1897 second Ader's airplane with two steam engines could not take the air.

Therefore, none of the flight attempts made in the 19th century was successful. Systematic failures, it would seem, proved the prematurity of airplane engineering and should have suspended all work in that area. However, at the turn of the 19th–20th century, a new precondition appeared for airplane engineering development: a device more compact and far more convenient than the steam engine for operation in transport, a gasoline internal combustion engine. But first aircraft with such power plant designed by W. Kress, K. Jatho, L. Levasseur and S. Langley also were unable to fly.

So, despite numerous attempts, engineering an airplane was not accomplished yet; in the best case scenarios, only short “hops” into the air, often ending up in a crash, were achieved. Then why, despite the high level of education among most of the airplane engineers and in some cases, government support (Ader and Langley aircraft), nobody could reach the objective for more than a quarter of a century? Was it a result of subjective circumstances (pilot error, faulty testing methods) or the inevitability of the crash was ingrained even at the airplane design phase?

The latter is correct. As calculations show, the airplanes built in 1870s — 1880s essentially could not take off due to heavy engines and insufficient lift of the flat wing. Starting from the 1890s, unsatisfactory stability and controllability of the airplane became the main obstacles on the path of airplane development. The inventors, relying on the experience in aerostatics and shipbuilding, believed that in-flight stability may be easily achieved by low placement of the center of gravity. The danger of disrupting the balance during wind gusts was either not considered at all, or it was mistakenly assumed that in order to eliminate it, providing wing or fins elasticity in vertical plane would be sufficient, and the machine would automatically dampen the airflows. Lack of lateral controls on the airplane is explained by the fact that there were no analogues on any means of transportation, and therefore, as it seemed, there was no need for it. In addition to poor stability, the first airplanes often did not have the strength sufficient for flight.

These flaws could only be detected and eliminated through practical experience. But there was no such experience, since at the first attempt at takeoff the airplane would, as a rule, break. The next design, possessing the same flaws, would once again turn out to be a failure, and so on. It was a never-ending circle, and the airplane essentially did not develop at all. The situation was exacerbated by the fact that the people financing the work did not understand the necessity of the refinement stage and, expecting an immediate success, would discontinue their support after the first failure.

The way out of this conundrum was gliding, which enabled the man to gain flying experience, review some of the design principles and finally create a workable airplane.

The first “flying machine” inventors did not think about creating a glider — the necessity for an engine to fly a heavier-than-air machine was considered to be an axiom. Only in the second half of the 19th century, when scientists researching birds' flight found out that their ability to remain in the air without wafting the wings is attributed not to some specific properties of the bird's body, but to the effects of updrafts, some aviation pioneers decided to attempt using the energy of moving air for flying an unpowered winged airplane.

Attempts to rise into the air on wings without the aid of an engine were made in Germany, in France, in England, in the USA. All of them failed: the machines were either unable to take off from the ground or, due to the flimsiness of the structure, were broken by the wind even before the tests.

However, the main obstacle in the path of glider development were not even the miscalculations made during the design phase (practical experience would have allowed eliminating them gradually), but incorrect estimations of an unpowered airplane's capabilities: prolonged soaring flight, like that observed in birds, was expected from the gliders. Very typical would be the announcement published in the April 1868 issue of *Aeronaute* magazine in regards to the expected trials of Le Bris glider at Brest: “After the first experiments Captain Bird (Le Bris. —

D.S.) will land on a field in Port-Napoleon, and from there in the presence of people, will take off and fly across the harbor, perhaps even outer harbor. It will have a parachute, so that if necessary, he can descend from the 300–500 m elevation where the air maneuvers would be performed”.

A turning point in the history of unpowered flights occurred when the glider became viewed not as an alternative to airplane or dirigible, but as a means of training to acquire piloting skills during gliding descents and a way to advance the design characteristics of fixed-wing airplane.

One of the first to correctly evaluate the place unpowered winged airplane would take in the aviation development was Russian doctor of medicine N.A. Arendt. In a book *On Aeronautics Based on the Principles of Birds Soaring*, published in Simferopol in 1888, he wrote: “...no, there isn't and shouldn't be such a model of an airplane that could be made to fly without applying skill... It is undeniably possible to engineer a device or a machine that in terms of its configuration would correspond to the flying apparatus of a squirrel (here he means the flying squirrel that has a membrane connecting its front and hind paws and serving as a wing. — D.S.); studying the matters of controlling this unsophisticated apparatus can't be an unreachable goal; a gradual transition from this prototype of an airplane and similarly prototypical form of soaring (by “prototypical form of soaring” Arendt implied glided descents. — D.S.) to more accomplished forms is quite logical”.

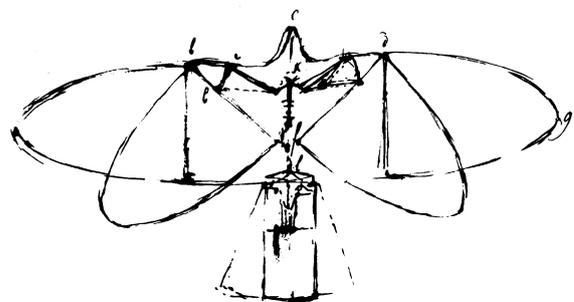


Fig. 3. Drawing by Arendt of a glider with a folded wing

The concept of using an unpowered airplane to learn the piloting techniques found its practical implementation thanks to the work

by a German engineer and experimenter O. Lilienthal. Possessing the material means to conduct full-scale experiments, Lilienthal could accomplish what Arendt only dreamed of. As a result of many years of persistent training, Lilienthal achieved a great mastery in flying a glider. By mid-1896 he completed over two thousand flights, with a distance sometimes reaching up to 250 m, and duration — up to tens of seconds. On a number of occasions the glider pilot managed to climb above the launch point, i.e. achieve soaring flight. Having reliably mastered the technique of weight-shift control, Lilienthal dared to fly at fairly high wind speeds.



Fig.4. Otto Lilienthal in flight

Lilienthal never had a chance to witness the development of gliding. On August 9, 1896 he died, falling from a 15 meter height when flying a glider.

Despite Lilienthal's tragic death, his work made a positive impact on the aviation development. For the first time in many decades of failed attempts to rise into the air without an aerostat, people witnessed flights using a heavier-than-air machine, and these flights were not just singular and accidental occurrences, they took place regularly, sometimes several times a day. This served as motivation to renew the work by the disciples of dynamic flight.

Not all Lilienthal's followers displayed the necessary persistence. Many abandoned gliding after the first, not particularly, successful trials. Some stopped the experiments after learning the news of Lilienthal's death. But there were others, who firmly decided not only to repeat the German glider engineer's achievements, but

accomplish more, improving the glider design and perfecting the piloting techniques. Among these enthusiasts were American inventors brother W. and O. Wright.

The Wrights decided to outfit their glider with movable surfaces, realizing that the forces developed by the aerodynamic rudders increase with larger glider size and wind speed proportionally to the causative moments and therefore the efficiency of the new control system does not depend on the size of the airplane and flying conditions.

In their work the Wright brothers could rely on the practical experience of glider flights. And that experience showed that besides yaw control, there must be a possibility to adjust the machine tilt in order to eliminate accidental rolls and to turn in the desired direction.

At first the Wrights intended to adjust the wing plane setting angle in opposing directions simultaneously, but soon came to the conclusion that the more convenient method would be conical wing twist (warping) along the wingspan. The warp value would be determined by the force applied to the control handle. In 1901-1902 Wright brothers accomplished about a thousand flights using the glider with an improved control system.

The idea of creating an airplane based on motorless vehicle occurred to the Wright brothers in the end of 1902 after successful tests of the second glider. They wrote in the letter on December 11: "We intend to build a significantly larger and approximately twice heavier vehicle than our present vehicle in the following year. We will use it to study the problems of starting and controlling a heavy device and, if we find it well controllable in flight, we will install the engine"[4]. Soon, however, it was decided to build the vehicle right away with gasoline engine, losing no time in testing its motorless version.

On December 17, 1903, the Wrights brothers managed to fulfill four short flights, of total duration less than two minutes. They made no attempts at maneuvering in the air, all four tests were stopped due to piloting errors. Still, it was a truly historical event: man flew on airplane for the first time, making several flights without speed and altitude loss within a single

day. Relying on the experience of their predecessors and their own glider building practice, the Wrights brothers created an airplane having not only the required power-to-weight ratio, aerodynamic quality and safety margin, but also an efficient lateral and longitudinal control systems, —the very thing lacking in the airborne vehicles of other aviation pioneers.

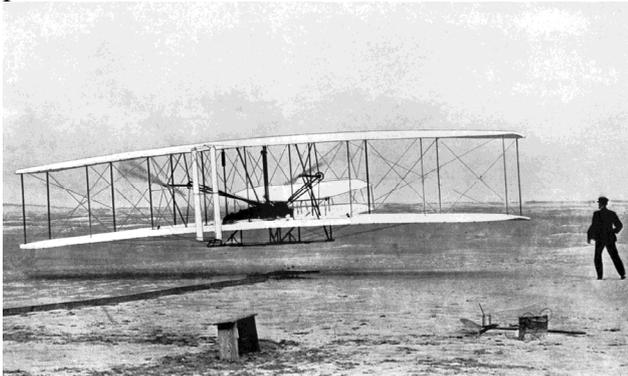


Fig.5. The flight of Wright's *Flyer* on December 17, 1903

The Wright brothers' success was considerably conditioned by the correct design method. As distinct from many of their predecessors and contemporaries, the Wrights did not rush from one design to another, but consistently and systematically improved the selected airborne vehicle type, successively combining in themselves the qualities of researchers, engineers, and test pilots.

However, Wrights' aircraft cannot yet be called a fully practical airplane. Given the absence of a wheel landing gear and low power-to-weight ratio, it had to take-off on a rail by means of catapult and, in case of forced landing far away from the landing point, was unable to get off the ground again. Moreover, it was not at all easy to fly the airplane due to its instability and the pilot's unusual lying position.

Thus, the creation of a practical airplane was not finished yet in 1905. The aforesaid shortcomings were overcome by the end of the first decade of the XX c. due to the activity of European, and first of all, French aviation pioneers.

Widespread among European airplanes and gliders of the beginning of the century was the biplane design with a box-like wing and fins.

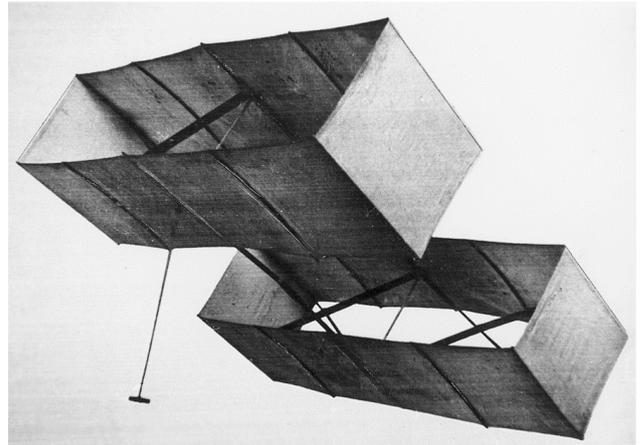


Fig. 6. Hargrave's box-like kite – a sample for many first French aircraft

The prototype of this configuration was the box-like kite invented in Australia in the 1890s by L. Hargrave. It became known in Europe a decade later, when in France was published information about the work of the Australian aviation enthusiast. On the basis of construction in 1906-1907 have been built first planes of A. Santos-Dumont, G. Voisen and some other French designers.

The same time L. Bleriot started making monoplanes aircraft. Gradually the monoplane idea gained more and more popularity in France. Making of such airplanes, besides Bleriot, commenced R. Esnault-Pelterie, L. Levasseur, A. Santos-Dumont and others. The total number of monoplanes built in 1907 exceeded the number of biplanes.

One of the peculiarities of airplane development in European countries in the first years of the XX century was the fact that designers acted by the trial and error method useful in XIX, but outdated in the XX centuries, when there already was certain experience in airplane design. As a result, much effort, resources, and time was wasted in creating admittedly unsuccessful airborne vehicles.

Besides, the view of the airplane, predominating among French aviation pioneers, as a "winged automobile", conditioned by their having no experience in glider flights, caused undervaluation of importance of controllability in flight. About half the airplanes and gliders, built in Europe in 1904–1907, had no roll controls.

It should also be noted that the first European airplanes were usually tested by persons having no flight skills and it is no surprise that flight attempts were consistently accompanied with accidents. Endless repairs heavily slowed down the tests.

And yet the specimens of French airplanes had a number of potential advantages over the *Flyers* of the Wright brothers by the beginning of 1908. Thanks to the good engines and wheel landing gear, they were capable of standalone takeoff, and their inherent stability, pilot's seated position and simpler control system facilitated piloting.

Thus, there were two main trends in the development of airplane industry at the beginning of the XX c. One was represented by the Wright brothers, the other — by European aircraft designers. Airplanes of both schools had advantages and disadvantages: the American *Flyer* was distinguished by good maneuverability, it could fly in case of wind, while European airplanes could take off without a catapult and had good stability. Due to the fact that the advantages of machines of one type were successfully complemented by the advantages of the other, merger of both trends might be the last step in creation of a truly good airplane. This step was made in the second half of 1908, when W. Wright made demonstration flights on the *Flyer* in France in 1908.

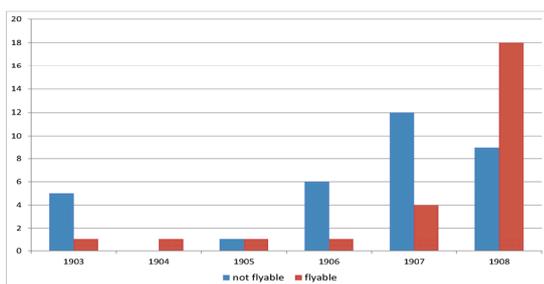


Fig. 7. Number of airplanes models, 1903-1908 [8]

European aircraft designers have quickly learned the lesson from what they saw. From 1909, the overwhelming majority of airplanes started being provided with efficient roll controls — wing tilting system or wing ailerons of increased surface area. The transmission became widely used for reducing rotor speed. Primitive metallic propellers were replaced by

the smooth wooden propellers with much improved efficiency.

These improvements, as well as a number of other innovations, e.g., Farman's creation of pedal control for deflection of the yaw rudder, have made it so that in 1909 the airplanes of French designers were as good as the Wright, and in many things surpassed it. The best models — *Bleriot-11*, *Farman-3*, *Antoinette-7* had a successful combination of stability and controllability and convenient control system. The possibility of standalone start allowed for flights outside airfields; the first such flight between the towns of range 27 km was performed by A. Farman on the airplane *Voisin-Farman-Ibis* on October 30, 1908. It is characteristic that all the records of 1909 were set up on French airplanes.

The first advances of the Russian aviation date back to the summer of 1910. On June 5, the professor of Kiev Polytechnic Institute A.S. Kudashev tested his biplane with a French 35 hp Anzani engine, and he, as witnesses testified, “managed to get off the ground twice and fly several tens meters” [5]; on June 16, the young aircraft designer I.I. Sikorsky covered about 150 m in the air on his airplane S-2, and three more days later, the airplane of engineer Ya.M. Gakkel flew, which differed from the other biplanes in having an enclosed fuselage, but not a simple design of several beams.

Three years ago Igor Sikorsky created the first multiengine airplane “*Russky Vitaiz*”. Its successful flights marked the dawning of heavy aviation development. Abroad such airplanes were built several years later than in Russia — during World War I.

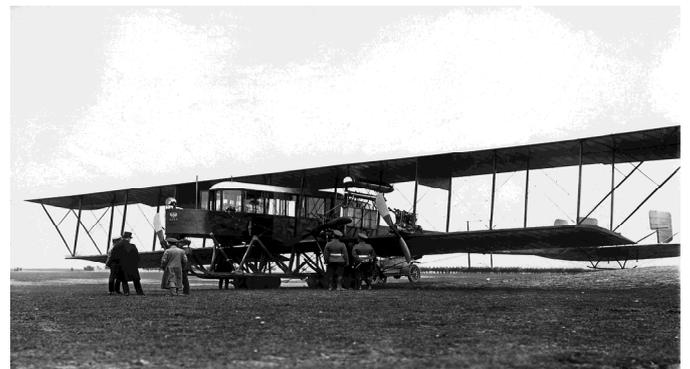


Fig. 8. Four-engine “*Russky Vitaiz*”, 1913

Thus, in the beginning of the 20th century the airplane stopped being a fancy or “eccentricity”, but became a reality. Uncontrolled “jumpers” were replaced by vehicles capable of long flights and maneuvering in the air. The airplane invention stage was finished, the stage of its practical use and serial production started.

There are many works ascribing the prevailing role in airplane creation to some specific inventor or representatives of a certain country. This view of aviation development is certainly erroneous. The airplane was created by efforts of tens of enthusiasts from different countries. It is truly an international invention.

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