# Flight is Not Improbable: Octave Chanute Combines Civil Engineering With Aeronautics

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## Abstract

**The English engineer Sir George Cayley worked out the basic principles of the aircraft at the turn of the 19th century. The German mechanical engineer Otto Lilienthal realized that building a successful aircraft required learning how to fly first. The American civil engineer Octave Chanute learned from his many predecessors that mechanical flight was certainly within the range of possibilities. As a careful designer and critical analyst, he progressed systematically by observing and interpreting the behavior of his various glider designs in flight, an essential step in the initial development of the aeroplane. Following in the footsteps of his predecessors, Chanute began an ambitious aerodynamic research program in the summer of 1896. It is a unique opportunity to reflect on the happenings of more than a century ago when few believed that flight is probable.**

## Introduction

After a successful civil engineering career, the fifty-one-year-old Octave Chanute resigned his high-paying position as chief engineer and assistant general superintendent at the New York, Lake Erie & Western Railroad Company in 1883 to start a private consulting practice. He had told fellow members of the American Society of Civil Engineers (ASCE) in 1880,

> If Engineers desire to take a higher rank than they now occupy in this country, they must study new paths for themselves, and be no longer men of routine, ordered hither and thither by promoters of schemes and the magnates of Wall Street [1].

He believed that visionary engineers are responsible for technical developments and inventions, and that they could solve just about every technical problem. Early in his working life, Chanute had become interested in manned flight; he had watched Silas Brooks inflate his balloon in Peoria in August 1856 and watched with amazement as the balloon and its passenger drifted away. Then his father, living in Paris, France, mailed him a 32-page pamphlet on the history of balloons and aerial locomotion [2], describing not only the many attempts to fly during the past centuries, but also how some inventors used the power of nature as they tried to achieve manflight. Seeing write-ups and images of various flying machines probably made him smile at times, but not knowing any better, Chanute clipped and filed everything on aeronautics in unlabeled wooden storage boxes, placed neatly in his bookcases. One example (Fig. 1) is the pamphlet by a P. P. Bailey, into which Chanute sketched his vision of how a propulsion system might be incorporated into the design. Chanute compiled a nine-page manuscript on "Mechanical Flight" in late 1878 [3] and another one in 1882; neither manuscript was published. In the interest of his career and his (or his family's) social standing, this topic was taboo, to be discussed only behind closed doors and away from the general public.

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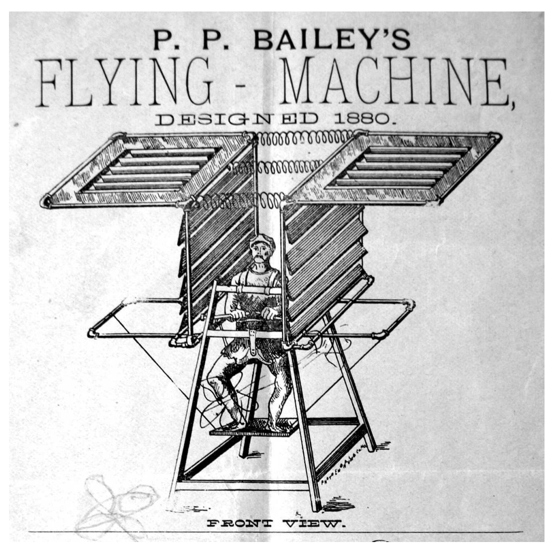



**Fig. 1: Pamphlet submitted by P. P. Bailey in 1880 to the United State Patent Office. Chanute Papers, John Crerar Library, University of Chicago**

## Background

The original charter of the British Institution of Civil Engineers (ICE) [4], adopted by their American counterpart (ASCE), defined:

> Civil Engineering is the art of directing the great sources of power in Nature for the use and convenience of man as applied in the construction of roads, bridges, aqueducts, canals, river navigation and docks, and in the art of navigation by artificial power for the purposes of commerce, and in the construction and adaptation of machinery.

Chanute fully agreed but puzzled, if nature provided birds the faculties to fly, then man should be capable to utilize the forces of nature, the wind or the sun, as motive power. There was nothing whatever irrational in the nature of the problem. Scientific research, exact computation, precise adjustment of well-understood conditions should lead to success.

Approaching now what he considered the end of his professional career, Chanute still yearned for challenges, excitement and new discoveries. With the approval of his family, he began investigating mechanical flight as a "side issue," while earning money as an independent engineering consultant and running his wood preservation works with his partner Joe Card.

To conceive "locomotive aérienne" Chanute knew that he had at least two major hurdles to tackle: the general negative attitude of the public toward anyone showing an interest in manned flight and then to design a flying machine capable of carrying a man. The public opinion would change sooner or later, but the flying machine concept was indeed complicated. In typical engineering fashion he took the heuristic approach and defined a series of questions to study: What are the basic aerodynamic requirements? What should the wing look like? How does air flow over or under a wing? What are the forces acting on wing surfaces as they cut through the air? Creative thinking, observation, and experimenting, he thought, should yield answers.

At the annual meeting of the ASCE, the current president traditionally presented a paper on the engineering advances of the past year. In his presidential address to ASCE members in June 1880 [1], Chanute discussed newly developed motive powers and expressed hopes that the last transportation problem, traveling through the air, would soon be solved. This is the first time that aeronautics was discussed in detail in the annual address on "Engineering Progress in the United States" by an elected officer of the most prestigious engineering society.

> I suppose you will smile when I say that the atmosphere yet remains to be conquered; but wildly improbable as my remarks may now seem, there may be engineers in this room, who will yet see men safely sailing through the air.

He knew that others had to be pulled into his research circle so that a successful, practical flying machine could be invented.

A year later, Robert Thurston, the first president of the newly formed American Society of Mechanical Engineers (ASME), also discussed aeronautics in his presidential address [5], wondering who the genius would be to fulfill Erasumus Darwin's prophecy of a "flying chariot" [6] and envisioned,

> The science of aeronautics progresses, although slow, but there is no department of engineering in which the art of the mechanic has opportunity for greater achievement. We have not yet learned to fly like Daedalus, and thus have escaped the fate of Icarus, but the navigation of the air is, very possibly, on the point of real advancement.

Chanute accepted the chairmanship of the Mechanical Science and Engineering Section of the American Association (Section D) for the Advancement of Science (AAAS) in 1886. Having read a communication by Israel Lancaster from Chicago in the Report of the Aeronautical Society of Great Britain on the flying habits of soaring birds [7], he wondered if this could provide insight into the potential for humans to fly. Traveling back to Kansas City, Chanute met the author and listened with amazement that soaring birds use air currents to remain airborne. A talk on the flight of soaring birds would surely be of interest to attendees, so he invited Lancaster to speak at Section D.

Discussing "Scientific Inventions" in his vice presidential address [8], Chanute briefly mentioned the possibilities of aerial navigation,

> inasmuch as I have noticed that whenever an imaginative writer pretends to give an account of future mechanical achievements, the first thing which is described is always a flying machine.

Lancaster's talk received mixed reviews by the press and attendees, but Chanute had achieved his goal: the talk stimulated interest and several intellectuals became curious about aerodynamics and lift. A new branch of scientific inquiry was born.

## The Second Aeronautical Congress in Paris, 1889

Keeping his ears and eyes open for anything aeronautical, Chanute read that World's Fair organizers in Paris planned on holding an international aeronautical congress. Participating would provide a good opportunity to meet like-minded professionals, so he volunteered to serve as the United States delegate and present a paper [9]. Chanute was sure that the neighbors back in Chicago would never hear about him being part of an aeronautical congress, and no one would point fingers at members of his family in the grocery store.

Throughout his long railroading career Chanute had to deal with friction and resistance in an effort to speed up rail transportation. Atmospheric resistance was especially puzzling as the varying forces of the wind complicated matters, so he made this the topic of his paper. To talk about flying with like-minded engineers was a somewhat accepted practice, but outside the engineering profession, many considered this topic terribly unorthodox. To better understand the physics and the laws which govern flight, he cautiously contacted several long-time engineering friends, including Robert Thurston [10]:

> I trust you will not think me a lunatic if I say that I have had in mind for years to devote part of my leisure time to the opening up of an inquiry, whether man can ever hope to fly through the air!! A single person can not carry out such an investigation, and I am looking for a number of other visionary students of science who will give thought to the subject and correspond with me.

The four-day aeronautical conference in Paris was a good education; he felt privileged to meet so many respected experimenters, all willing to share their knowledge and discuss their experiences. One of them was the civil engineer Gustave Eiffel who not only discussed his difficulties designing and then building the Eiffel tower, but he also invited the American engineer to his laboratory on the second level of the tower and demonstrated how he determined air resistance of various shaped objects using a variety of instruments (Fig. 2). Eiffel documented his work in Ref. 11, which Chanute acquired for his library.

Another interesting person was the Russian engineer Stéphane Drzewiecki from Petersburg who told his listeners that lift and drift (today we would call drift "drag") needed to be recalculated for each curved wing shape. The wing shape was highly important, as success and failure of any proposed flying machines would depend upon the sustaining effect (assuming that a light motor could be found), between a plane surface and one properly curved to achieve maximum lift.

Discussing mechanical flight with the more than 100 attendees, Chanute detected "utter disagreement and confusion" and wondered if artificial flight was really as absurd as some people thought or if an intellectual could solve it? Complex inventions, like the flying machine, require a variety of talent, for no one person is likely to be simultaneously an inventor, to imagine new shapes and new motors; a mechanical engineer, to design the arrangement of the apparatus; a mathematician, to calculate its strength and stresses; a practical mechanic, to construct the parts, and a syndicate of capitalists, to furnish the needed funds. But in Chanute's opinion, it was the job of the civil engineer to coordinate and organize all these efforts to achieve final success.

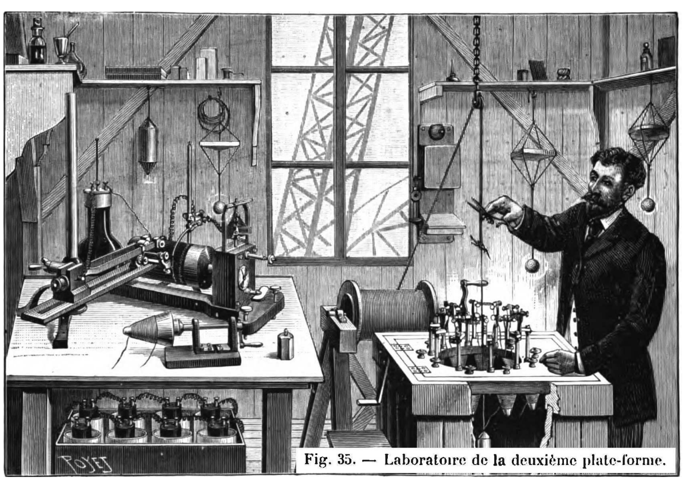



**Fig. 2: Gustave Eiffel in his aeronautical laboratory in the second level of the Eiffel tower. From [11].**

## The Civil Engineer Goes To Work

No one appeared to have exact information on requirements for flying machines. Years earlier, Chanute recalled being part of a group of civil engineers who pushed hard for a government sponsored facility to test the various shapes of bridge members that were affected by wind [12]. Now someone should initiate scientific testing of flat, concave and convex surfaces to determine the most efficient wing shapes.

In the late 1880s, with the industrial movement being in full swing, engineering education evolved rapidly as technology advanced. To broaden the horizon of his students and to raise the standard of technical education, Robert Thurston, now director of the Sibley College of Mechanical Engineering at Cornell University, introduced a lecture series by nonresident lecturers. Being interested in aeronautics himself, he invited well-known researchers to discuss their aeronautical work. The fifty-eight-year-old Chanute went to Ithaca on 2 May 1890, and Thurston announced, "This lecture will be especially valuable, treating as it does a subject that has usually been considered visionary in the extreme."

Lecturing on the unconventional topic of aeronautics in an academic surrounding [13], Chanute selected his words carefully. Going public was a breakthrough for him, but he looked for inventive young minds to supply fresh ideas to help him solve the century-old problem. One of the attending students, twenty-eight-year-old Albert Zahm, later described Chanute as

> a silver-haired gentleman, full of faith in the art, but apologetic for identifying himself with a pursuit so generally condemned. Mr. Chanute began with a hesitancy amounting almost to reluctance, seeming to entreat the young men not to believe that the study of such a subject was a more than probable indication of failing mental vigor [14].

The fact that so many gifted scientists and engineers studied the unsolved problem of artificial flight afforded a strong presumption that sooner or later a successful motor-driven flying machine would be an accomplished fact. Now the general public needed to know that perfectly sane men, and not just "cranks," were studying the unsolved problem of manflight.

> A measurable success appeared to be in sight with flying machines, which promise high speeds and the elements of an eventual success, the commercial uses of which are not as yet very clear, have gradually accumulated during the past half century.

Chanute then expanded his Sibley lecture with drawings and tables and offered the manuscript to the Scientific American; the editor rejected it. He then offered the manuscript to his friend Matthias Forney, owner and publisher of the Railroad and Engineering Journal, the most widely read engineering magazine in the US, who gladly published the expanded lecture in five installments [15], simply entitled "Aerial Navigation."

Having a prestigious journal and a highly regarded engineer tackle the topic did indeed give certain credibility to the questionable, but fascinating, subject of aeronautics. To learn, and then share, what others had accomplished or where they had failed, Chanute researched everything related to manflight and aeronautics. Starting in October 1891 he submitted monthly articles to the Railroad and Engineering Journal [16], using images from the French pamphlet Histoire des Ballons et des Locomotives Aériennes [2] and from Emmanuel Dieuaide's Tableau d'Aviation [17].

In the conclusion Chanute summed up the "state of the art" and laid down the fundamental requirements for a man-carrying flying machine:

1. The resistance and supporting power of air.
2. The motor, its character and its energy.
3. The instrument for obtaining propulsion (= propeller).
4. The form and kind of the apparatus (= airframe).
5. The extent of the sustaining surfaces (= wings and tail).
6. The material and texture of the apparatus.
7. The maintenance of the equilibrium.
8. The guidance in any desired direction.
9. The starting up under all conditions.
10. The alighting safely (= landing) anywhere.

Propulsion was just one obstacle. Currently available steam engines were much reduced in weight so that they might be employed as motors for flying machines, but Chanute theorized that

> it is possible to utilize a still lighter power, for we have seen that the wind may be availed of under favorable circumstances, and that it will furnish an extraneous motor which costs nothing and imposes no weight upon the apparatus. Just how much power can be thus utilized cannot well be told in advance of experiment; but we have calculated that under certain supposed conditions it may be as much as some 6 H.P. for an aeroplane with 1.000 sq. ft. of sustaining surface; and we have also seen that while but few experimenters have resorted to the wind as a motor, those few have accomplished remarkable results.

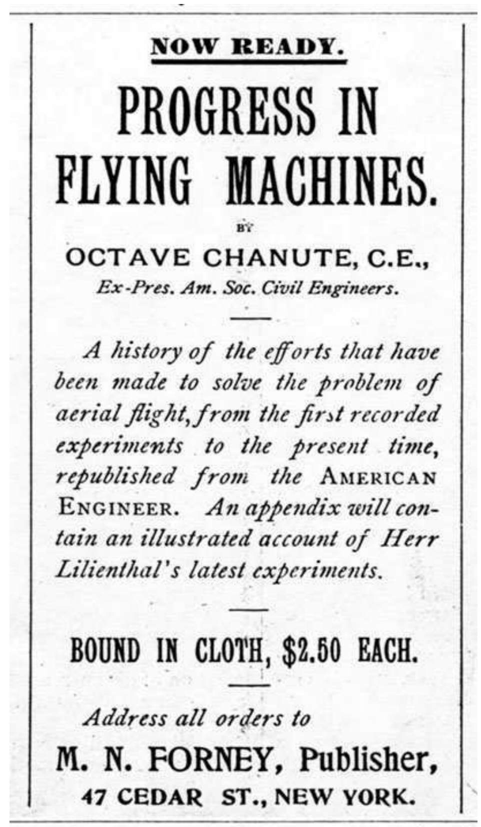



**Fig. 3: Book Advertisement in the Railroad and Engineering Journal, May 1894.**

Forney combined the 27 articles and published them in book format as "Progress in Flying Machines" in April 1894 [18]. The book was advertised regularly in the Railroad and Engineering journal (Fig. 3) and other engineering papers. He had about five hundred sets of pages printed and had two hundred books bound in the spring of 1894. The remaining pages were bound in 1899 with a new title page. This book never hit the best-seller list but it quickly became the definitive publication on the history and current status of flying machines. It became the standard reference work for anyone interested in aeronautics. Here, Chanute also formalized some terminology (aeroplane, lift, drag, aeronautical engineer) that would become a standard nomenclature in the future.

As part of his fact gathering, Chanute identified flight enthusiasts and experimenters and began a worldwide correspondence. He gathered and distributed information, spread news of what was going on elsewhere, offered encouragement and provided occasional financial support. This conduit was vital for the exchange of ideas as the invention of the airplane evolved. Chanute considered himself the "guiding light" and enjoyed talking about his eccentric hobby in the company of open-minded engineers, but in the real world, people usually still tapped their foreheads while exchanging significant glances when the conversation turned to flying machines [19].

## Manned Flight is Possible

The upcoming World's Fair in Chicago was to illustrate the development of transportation via rail, wheel, water and air [20]. Albert Zahm, now Professor of Mechanical Engineering at the University of Notre Dame in South Bend, Indiana, proposed to include an aeronautical conference similar to the one staged in Paris in 1889. At first Chanute hesitated to accept the chairmanship of this 3rd International Conference on Aerial Navigation, as he was concerned that "cranks", to use an American slang word, and dreamers might disrupt this academic gathering. But fellow members of the Western Society of Engineers were supportive, so he reluctantly agreed as such a conference would surely draw worthy inventors. He knew quite well that the principal object of any international conference was to compare opinions and share views on matters (such as aerial navigation), ascertain the problems that engage the thoughts of sober experts and exchange information. Such a conference would be a good opportunity, as "the greater the number of minds that can be brought to bear upon a particular problem, the greater is the chance of early success." As a certain safeguard committee members had to approve all papers before they were read in public, and to prevent uninvited spectators from disrupting the conference, every person who wished to attend had to purchase a "personal card of admission" for $3.

The highly successful 1893 aeronautical conference attracted a new generation of enthusiasts, but it also attracted legislative attention. Senator Cockrell introduced a bill in December 1893 to secure aerial navigation [21], but politicians ignored it, just as they had in the past. But people like Chanute, James Means, Samuel Langley and others continued to publicize the idea that manflight was an acceptable science; engineers and scientists just had to figure out the basic laws of aeronautics and arrive at a solution of the much-vexed question.

Early in 1895 Hermann W. L. Moedebeck mailed a copy of his "Taschenbuch" [22] to Chanute. Even though the book was written in German, the figures and tables did not need much translating. Seeing Otto Lilienthal's article with his table of air pressures, Chanute succeeded to calculate lift and drift on wing surfaces of 1/12th curvature, so he included the table in his follow-up article on "Sailing Flight" together with his interpretation of soaring:

> The simplest and most satisfactory explanation thus far is that which assumes ascending columns or trends of wind to exist at opportune times and places, but that it does not account for the cases in which all observers are agreed that the wind is horizontal.

This article [23] with the translated Lilienthal table contributed significantly to the development of the aeroplane during the next decade.

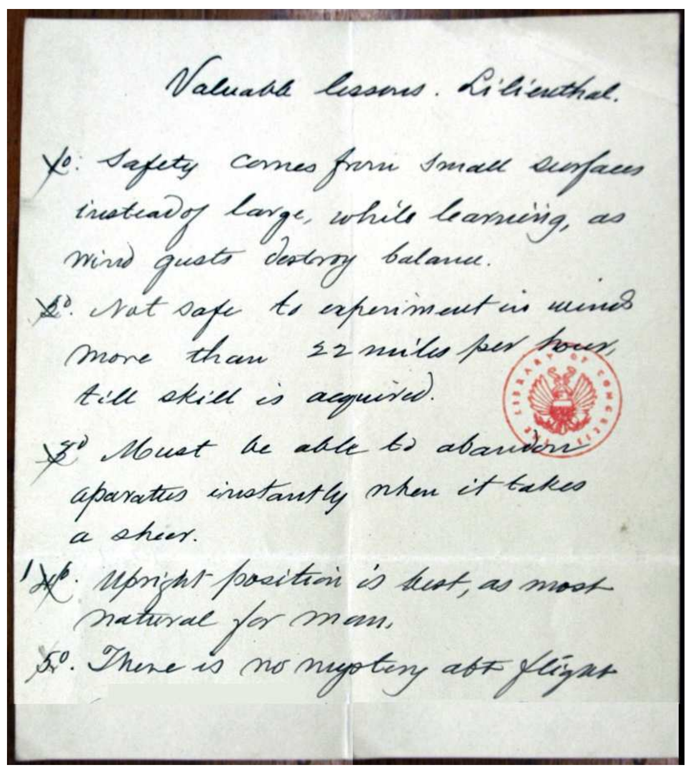
To proceed beyond the theoretical aspect of how manflight could be achieved and to determine the most efficient wing shape for his flying machine, Chanute hired Augustus Herring in early 1895 to build and test three wing shapes by mounting them on a bicycle, driving in a steady speed over the road. Next, utilizing what they had learned, Herring built several flying models to test what they had learned more accurately.

## From Theory to Investigating

The year 1896 was a turning point in aeronautics. The accomplishments of earlier flying machine inventors were surpassed by three major players: the mechanical engineer and industrialist Otto Lilienthal from Germany, Samuel P. Langley, a self-educated physicist and Secretary of the Smithsonian Institution, and Octave Chanute, a self-educated civil engineer, best known for taking the railway system as far west as Kansas and Nebraska.

Starting in 1891 Otto Lilienthal had developed more than a dozen different gliders. The "Flying Man's" efforts received worldwide attention and his fascinating reports with clear photographs were published widely. Lilienthal showed by word and example that mastery of flight can be accomplished in gliders. He reported soberly and candidly what he had done in practical flying and he invited others to repeat his experiments to improve on them. Unfortunately he died on 10 August 1896 from injuries sustained in a crash of his glider, ending a promising aeronautical career. Chanute later compiled a list of lessons learned from Lilienthal (Fig. 4).

Samuel P. Langley succeeded in May 1896 to launch and fly



Valuable lessons. Lilienthal.

1°. Safety comes from small surfaces instead of large, while learning, as wind gusts destroy balance.

2°. Not safe to experiment in winds more than 22 miles per hour, till skill is acquired.

3° Must be able to abandon aparatus instantly when it takes a sheer.

4°. Upright position is best, as most natural for man.

5°. There is no mystery abt flight

**Fig. 4: Chanute's memo on lessons learned after reading write-ups by Otto Lilienthal in 1894 and 1895. Chanute Papers, Library of Congress.**

his steam-powered model aircraft, aerodrome No. 5. The model with a fifteen-foot wingspan remained in the air for one minute twenty seconds, climbing to an altitude of 70 feet and covering a distance of three-quarters of a mile. Langley was convinced that he had successfully tackled just about all the hurdles of man-flight.

In late 1895, Chanute decided to devote energies and money to the invention of the flying machine. He hired William Avery, a local carpenter and competitive sailor, to build the "soaring machine". However this project was more demanding than first anticipated. When Augustus Herring asked to be rehired, Chanute agreed and the Herring family moved to Chicago in January 1896.

Having studied Lilienthal's American patent [24] in depth, Chanute had submitted his improvements to the Lilienthal glider to the United States Patent Office [25]. He now wanted to incorporate his claims into the Lilienthal-type glider that Herring had brought along, as they were thought to be essential to achieve longitudinal (pitch) stability.

Six weeks after Langley's successful launching of his unmanned aerodrome, the excitement began for Chanute's team. On Monday morning, 22 June 1896, the men carried gear and supplies for the next two weeks to the nearby Englewood Station in Chicago. The Lake Shore & Michigan Southern express train left at 7:24 am, arriving at Millers, Indiana, one hour later, causing a hum of excitement among the locals. It was a colorful group stepping off the morning train: Chanute, a distinguished-looking older man with a gray mustache and imperial, his son Charley, Avery, Paul Butusov and Herring with his two dogs. Each person carried odd-looking luggage over the mile-long road from the railroad station to the dunes.

The two locations that Chanute and his team visited in 1896 are not easily found on today's map. Figure 5 shows a portion of an 1894 railroad map, with Miller Station (today an eastern suburb of Gary, Indiana) and Dune Park (today the site of the Alcor Steel plant in Portage, Indiana) highlighted.

After pitching their tents, the men assembled the Lilienthal glider first, as Chanute wanted to validate the work done by others and separate fact from error before venturing into the unknown to discover the unanticipated. Herring was the first to launch with his glider into the wind, looking like a huge butterfly with concave wings, slowly settling to the ground [26]. But the Lilienthal-type did not perform as expected, or as Chanute recorded in his notebook [27], "the apparatus is cranky." Watching the glider in flight confirmed his concerns about stability, as the pilot had to be an acrobat to keep the craft under control. After making about fifteen jumps, the glider turned over on landing without hurting its pilot and was broken past mending. "Glad to be rid of it," Chanute recorded in his notebook. To make this a true sport, flying had to become much easier and safer.

## From Investigating to Trials

While the eagles and gulls flew effortlessly overhead, demonstrating how flying ought to be done, the men assembled

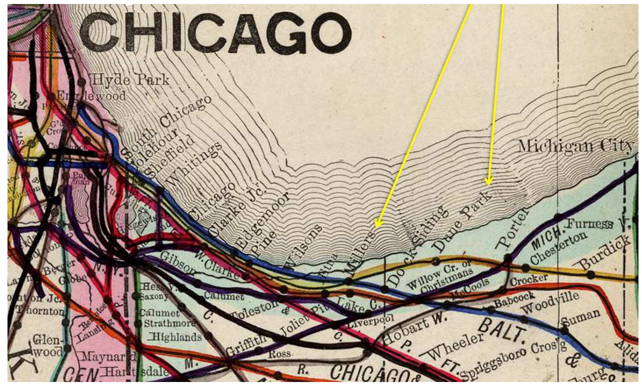



**Fig. 5: The southern shore of Lake Michigan, showing the two locations, Millers and Dune Park, where Chanute and his team performed gliding experiments in 1896 and 1897.**

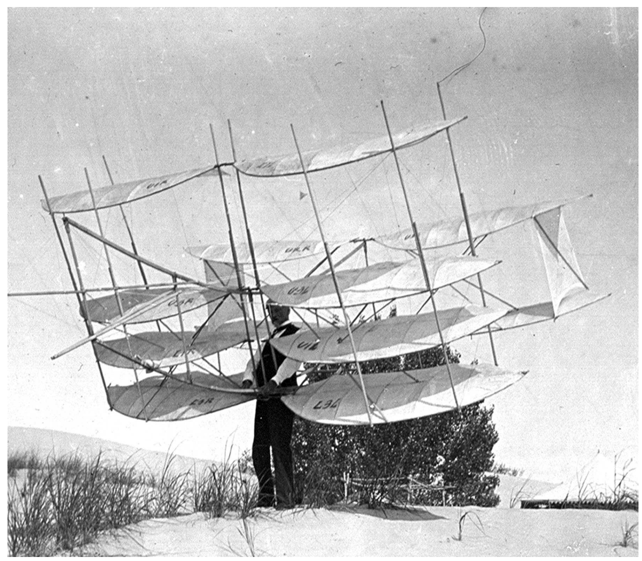


**Fig. 6: The Katydid, a multiplane glider that functioned as a flight test model. Chanute Papers, Library of Congress.**

Chanute's "soaring machine" next. This glider had twelve wings, each six feet long and three feet wide. Closely woven cloth was stretched tightly over the wing surfaces and coated with pyroxelene. Upon drying the wings became airtight and rang like a drum when tapped with the knuckles. Lilienthal had used collodion, but Chanute preferred pyroxelene, a mixture he had used on windmill blades in Kansas and Nebraska decades earlier. This soaring machine was to glide at angles of three to seven degrees in light breezes and eventually soar in stronger winds, either in spirals in a ten-mile breeze or in aspiration in a wind blowing at twenty miles an hour. In Chanute's vocabulary, "ascension" meant gaining altitude after takeoff, while "aspiration" was the performance of a bird using air currents to be drawn forward to achieve soaring flight.

The multiplane was indeed a research craft, that went through all kinds of changes. One of the final versions is shown in Fig. 6.

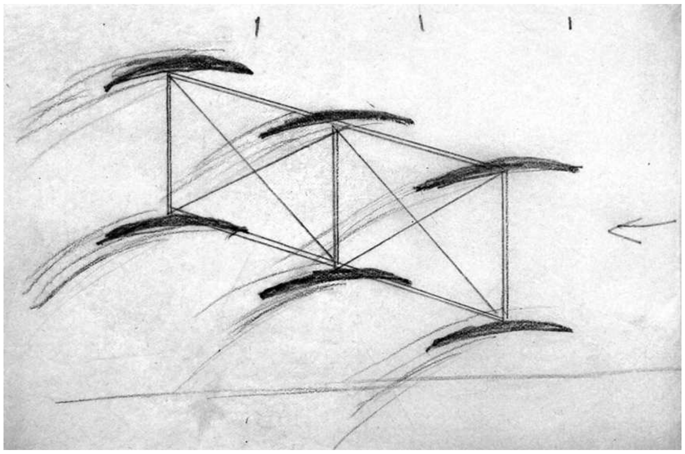


**Fig. 7: Studying the flow of the wind over the wings with the help of down feathers, Chanute could figure out how to increase the efficiency of the grouping. Chanute Papers, Library of Congress.**

After only a few flights it became apparent that the wings greatly interfered with each other. In typical engineering fashion, each wing had an identification number to easily keep track of any changes. Methodically, Chanute altered the glider's architecture in a step-by-step process to ascertain the most efficient grouping of the wings to achieve maximum lift and the greatest stability. Each flight was critically analyzed and recorded in his little brown notebook [27].

> The paths of the wind currents in each arrangement of the wings were indicated by liberating bits of down in front of the machine, and, under their guidance, six permutations were made, each of which was found to produce an improvement in actual gliding flight over its predecessors.

See also Fig. 7.

Slowly, the craft evolved from a ladder kite to an ordinary multiplane glider. The resulting Katydid, named after the midwestern grasshopper, could be handled in twenty-mile wind and the operator needed to move only two or three inches and not the acrobatic fifteen to eighteen inches that Herring's Lilienthal-type had required. In a thirteen-mile breeze, the Katydid could glide with its pilot in an angle a little better than one in four.

Figure 8 shows the multiplane in flight. The Katydid finally performed as Chanute had hoped that his "soaring machine" would.

Chanute's team returned to Chicago on Saturday, 4 July, late in the afternoon. During their two weeks of flight experimenting, each team member learned about the constantly changing wind and the updrafts along the dunes, but they also learned how to launch and control the aircraft in flight and then land safely.

**Fig. 8: 2 July 1896. Chanute's entry in his notebook reads: Found machine quite steady and manageable. The lift was greater and the head resistance apparently less. Took scores of glides. Chanute Papers, Library of Congress.**

## From Triplane to Biplane

Back in Chicago the findings of their flight research with the multiplane glider were incorporated into the next design. With the knowledge gained, Chanute now had more ambitious plans:

> I shall now proceed with the construction of two or three machines, to pass from the toboggan stage of air jumping to some attempt at soaring. I find that there is a vast difference between experimenting with models and with full sized machines with a man on them, as the wind is constantly changing in trend, in direction and in form, and gliding becomes an acrobatic exercise. [28]

Having learned how to efficiently position the wings in the Katydid, Chanute sketched a triplane and handed the paper to Herring to have the new glider built in Avery's shop. This new flying machine showed ingenuity: the boxy structure mirrored his bridges, providing similar three-dimensional strength and rigidity. To reproduce the wing of the soaring birds, Chanute consulted with John Johnson of Washington University about the characteristics of rattan. Using this wood allowed shaping the ribs in a circular-arc curvature with a height of about 1/12th of the width. Silk cloth was stretched tightly over the wing surfaces and made airtight using pyroxelene.

The glider had three superposed surfaces with a sixteen-foot wingspan and a four-foot, three-inch chord. The uprights were made from spruce while steel wire braced the wings in a Pratt truss pattern to give rigidity with a certain amount of flexibility. Chanute later explained to Sam Cabot how he determined the wire size:

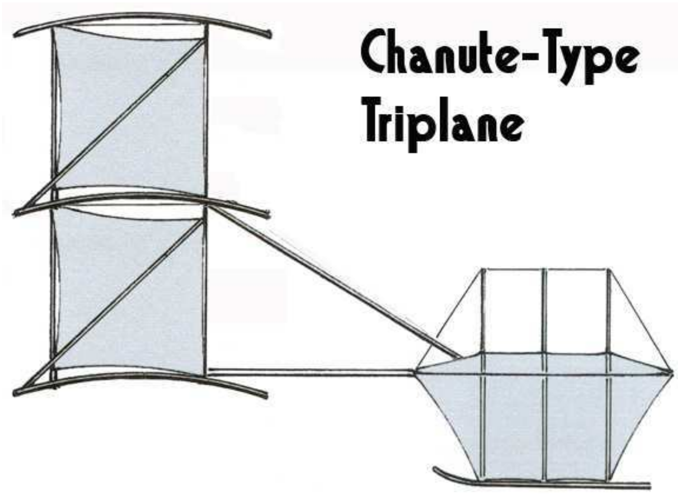



**Fig. 9: No photos exist of the triplane, only a variety of notes in the Chanute Papers. Drawing by Reinhard Keimel.**

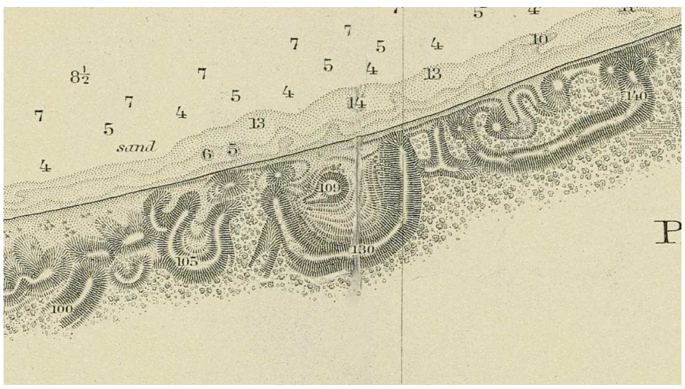


**Fig. 10: The Dune Park area, cut from an 1894 Coast Guard map of the southern shore of Lake Michigan, Regenstein Library, University of Chicago.**

> Having decided upon the weight to be supported, we calculated the amount coming on each post at the panel point, and its diagonal resultant along the wire. This gives us diameters varying from two to five hundredths of an inch, with a factor of safety of five, and we took the nearest commercial size to that [29].

The resulting triplane with a 191 square foot wing surface and Herring's regulating tail (an elastic cord with a spring and a hinge assembly between the main frame and the tail) weighed 30 pounds. No photos exist of the triplane, either on the ground or in the air, but we do have calculation notes in the Chanute papers which supplied the necessary information. Reinhard Keimel from Vienna, Austria, supplied the three-view drawings (see Fig. 9).

Chanute's team returned to the dunes along the southern shore of Lake Michigan on Friday, 21 August, this time coming by boat instead of the railroad. The coast guard map (Fig. 10) does not show the railroad that brought visitors and supplies to the Dune Park area, but it clearly shows the topography of the dune area. The triplane glider was first flown on 29 August; the bottom wing with the cutout for the pilot usually got caught in the sand during takeoff, so Avery suggested removing it and Herring repositioned the Pénaud-type tail with his "regulator". The resulting machine was a Pratt-trussed biplane glider. "This machine proved a success, it being safe and manageable." The biplane in its final configuration is shown in Fig. 11.

**Fig. 11: Sailing along in the biplane. Chanute Papers, Library of Congress**

On 11 September 1896 steady northerly winds of twenty-five to thirty miles per hour blew against the dunes, allowing several long flights with a much shallower angle of descent than the glides with no wind on the previous days. The visiting Chicago Tribune reporter Henry Bunting reported,

> With the high wind the practice was full of excitement. One wholly new freak of the air was experienced by Mr. Herring when his machine rose with a sudden gust forty feet higher than the starting point, then coming to a sudden poise, balancing like a bird, swooping at a right angle, traveled a long journey, and alighted gracefully upon a hillside. It was seen that Mr. Herring's flight with the wind alone caught and held the machine, then let it descend gradually and alight safely every time. [30]

Documenting their findings, Chanute wrote:

> It was found that by moving the operator's body backward or forward, an undulatory course could be imparted to the apparatus. It could be made to rise several feet to clear an obstacle, or the flight might be prolonged, when approaching the ground, by causing the

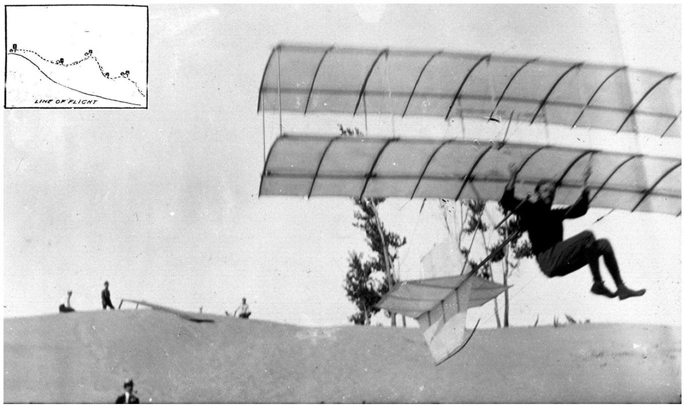


**Fig. 12: Tobogganing on the air in 1897. Note the many visitors who came to help and try the new sport as well. Chanute Papers, Library of Congress,**

> machine to rise somewhat steeply and then continuing the glide at a flatter angle. It was very interesting to see the aviator on the hillside adjust his machine and himself to the veering wind, then, when poised, take a few running steps forward, sometimes but one step, and raising slightly the front of his apparatus, sail off at once horizontally against the wind; to see him pass with steady motion and ample support 40 or 50 feet above the observer, and then, having struck the zone of comparative calm produced by eddies from the hill, gradually descend to land on the beach several hundred feet away.

A total of about 330 flights of various length and duration were made in the summer/fall of 1896 by a variety of people, not only by members of Chanute's team. The following year, in 1897, a revised biplane was flown in the Dune Park area again, but this time there were many visitors and spectators who all enjoyed the tobogganing on the air (see Fig. 12). Some of these flights were very short and Chanute called them "jumps", others were longer or "runs" and finally they made "glides" or "flights" (Table 1). The longest flight was 359 feet and 14 seconds by Herring on 12 September (without observers), and about 290 feet by Avery and Herring the previous day with everyone in camp watching.

**Table 1: Breakdown of flights made in 1896 by Chanute's team**

| | |
|---|---|
| 22–26 June | About 15 jumps in Lilienthal-type glider |
| 23 Jun – 4 Jul | About 80 jumps, runs or flights in Katydid |
| 4–23 Sep | About 30 flights in redesigned Katydid |
| 29 Aug | About 5 jumps in triplane |
| 31 Aug | Triplane was cut down to a biplane glider |
| 31 Aug – 23 Sep | About 200 flights in biplane |

Chanute was pleased about the overall progress but somewhat disappointed that the flight trials had not achieved sustained flights over longer distances. "Not even the birds could have operated more safely than we, but they would have made longer and flatter glides, and they would have soared up into the blue" [31]. He noted in his diary that neither machine could perform true soaring flight and explained to James Means: "The bird easily glides [in an angle of] 1 in 10, and I have not been able to get an artificial machine to do better than 1 in 6" or six feet forward for every foot in vertical descent [32].

## Flying Flivver is Assured

By systematically approaching the problems of flight Chanute moved solutions forward through experimentation and observation, developing the most successful glider up to that time. What he had learned in his long career as civil engineer designing bridges and other structures, he had now translated into a man-carrying glider by introducing the Pratt-trussed biplane configuration to aviation. Given the depth of Chanute's talents as an engineer and his encyclopedic awareness of aeronautical activities around the world, it is not surprising that his 1896 glider design represented the state of the art. This little biplane glider was a critical step forward in the evolution of the aeroplane. It had proven the ideas that preceded it and embodied the progress toward maintaining equilibrium and exerting limited control. The biplane configuration with cruciform tail became a model for aircraft design for many years hence, but the application of propulsion and effective control remained for the next generation of flying machine experimenters to introduce.

## Conclusion

The invention of the aeroplane clearly began in the 19th century. The aeroplane, like most human inventions, had gone through a process of experiment, evolution and improvement, which paved the way for the final result. In the 1890s, able men like Hargrave, Langley, Lilienthal, Maxim, Pilcher and Chanute made substantial progress and significant advances in the "inchoate art of aeronautics." The work and efforts of these people came to fruition in the early part of the 20th century, when other experimenters became involved and improved the design of the aeroplane to fly faster, further and higher.

Believing that final success could only come when different people worked the problem from various angles, Chanute took the lead and became the clearinghouse for the world's knowledge of aeronautical and kindred subjects. To encourage good work in research, publishing, and the construction and testing of kites and aeroplanes, he established prizes. Being a realist, he also knew that he would not be the one to perfect the practical aeroplane, but he hoped to be remembered for furnishing the important prototype.

The effect of Chanute's efforts became obvious during the next decade.

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