Flight Not Improbable,
Octave Chanute Tackles Aeronautics as a Civil Engineer

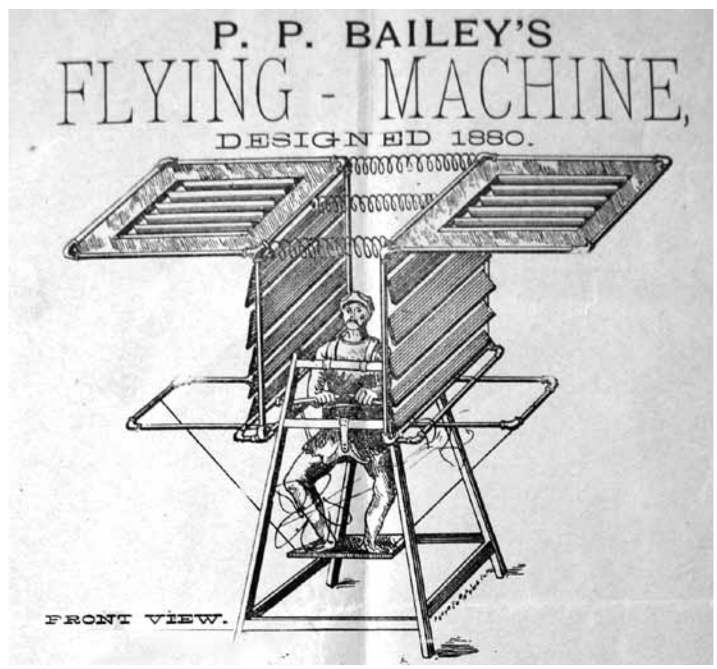
By Simine Short
Chair, Landmark of Soaring Program
National Soaring Museum, Elmira, New York 14903

The English engineer Sir George Cayley worked out some of 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 believed, based on the work of 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 development of the aeroplane. Chanute's work in 1896 constitutes the first true aerodynamic research program, making him the first flight test engineer. We now have a unique opportunity to reflect on the happenings of more than a century ago when few believed that flight is probable.

After a successful career in civil engineering, the 51-year-old Octave Chanute resigned his high-paying position as chief engineer and assistant general superintendent at the New York, Lake Erie & Western Railroad Co. in 1883 to start a private consulting practice. He had told fellow American Society of Civil Engineers (ASCE) members 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 were responsible for technical developments and inventions, and that they could solve just about any technical problem.

Early in his working life, Chanute had become interested in manned flight; he had watched Silas Brooks inflate his balloon in Peoria, Ill., 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 writeups 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. He compiled a nine-page manuscript on "Mechanical Flight" in late 1878 and another one in 1882; neither manuscript was finished and thus not 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.



Cover page of pamphlet submitted by P. P. Bailey in 1880 to the United States Patent Office. (All images from the author unless otherwise noted)

Background

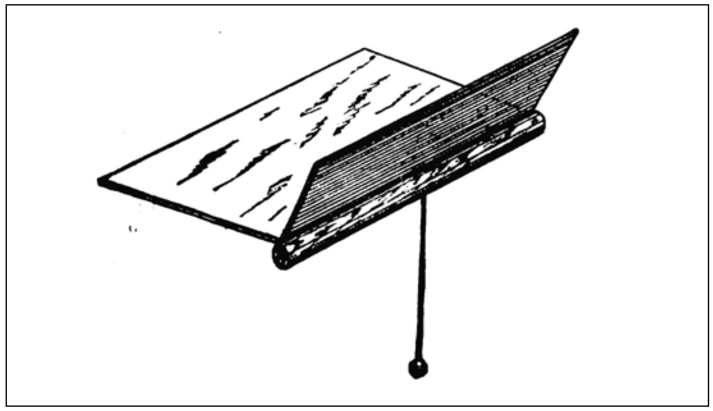
The original charter of the British Institution of Civil Engineers (ICE),[3] adopted by their American counterpart, ASCE, defined: "Civil Engineering is the art of directing the great sources of power in Nature for the use and convenience of man as applied in the construction of roads, bridges, aqueducts, 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 with that philosophy and theorized, 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 what he considered the end of his corporate career, the 51-year-old 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 he continued bringing money into the household as an independent engineering consultant and managing his wood preservation works.

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. 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 also 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 some 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 included the topic of aeronautics in his presidential address,[4] wondering who the genius would be to fulfill Darwin's prophecy 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."



Israel Lancaster's Soaring Effigy. (*Scientific American Supplement*, October 16, 1886)

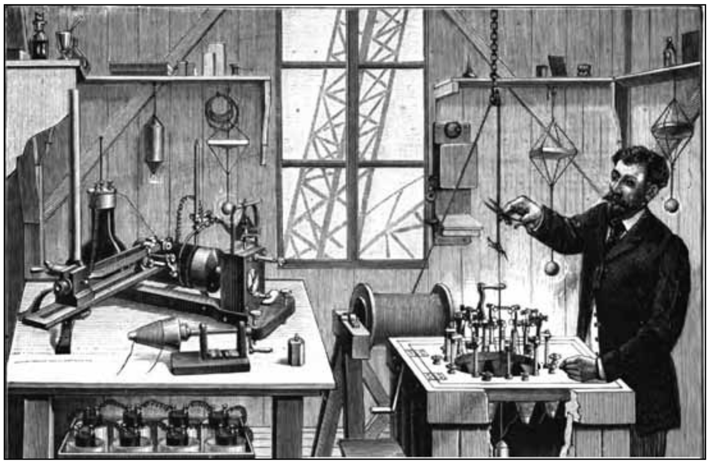
Chanute accepted the chairmanship of the Mechanical Science and Engineering Section of the American Association for the Advancement of Science (AAAS) in 1886. Having read a communication by Israel Lancaster from Chicago in the *Report of the Aeronautical Society of Great Britain* on the flying habits of soaring birds,[5] he wondered if this could provide insight into the potential for humans to fly. Traveling back to Kansas City, Chanute met the author in Chicago 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 of the upcoming AAAS meeting in Buffalo, New York.

Discussing "Scientific Inventions" in his vice presidential address,[6] 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[7] discussing soaring flight and his effigies attracted attention but received mixed reviews by the press and attendees; the *Science* editor reported dryly that Section D probably needed recreation. But Chanute had achieved his goal: the talk stimulated interest and several intellectuals, including Samuel P. Langley, director of the Allegheny Observatory in Pittsburgh, Penn., and De Volson Wood,[8] Professor of Mathematics and Mechanics at Stevens Institute of Technology in Hoboken, N.J., became curious about aerodynamics and lift. A new branch of scientific inquiry was born. "How often is it that the imagined things of today become the accomplished things of tomorrow?"

The 2nd 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 in Chicago would never hear about him being part



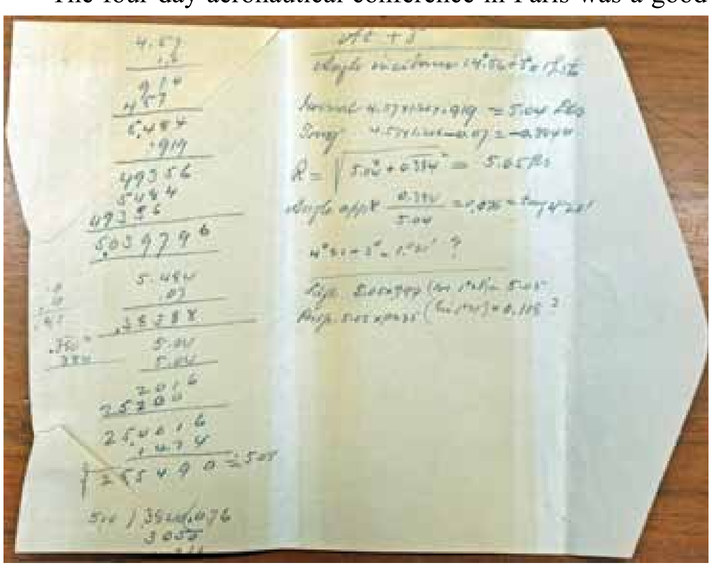
Gustave Eiffel in his aeronautical laboratory in the second level of the Eiffel Tower.[12]

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 still considered this topic terribly unorthodox and impossible, just like perpetual motion.

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 cannot 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, and he felt privileged to meet so many respected engineers and experimenters, all willing to share their knowledge and discuss their experiences. One of them was the civil engineer Gustave Eiffel who not only talked about the difficulties designing and then building the Eiffel tower, but he also invited the American engineer to his laboratory on the second level of the Eiffel tower and demonstrated how he determined air resistance of various shaped objects using a variety of instruments.[11]



An engineer never wastes a good envelope for scribbling notes to remember. Here are some calculations on angle of incidence. Early 1890s? (Chanute Papers, LoC)

Another interesting person was the Russian engineer Stéphane Drzewiecki from Petersburg who told his listeners that lift and 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) of a properly curved sustaining surface to achieve sufficient lift.

Discussing mechanical flight with the more than 100 attendees, Chanute detected "utter disagreement and confusion" and he became concerned as to whether 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 Chanute thought that it was the job of the civil engineer to coordinate and organize all these efforts to achieve final success.

The Civil Engineer Goes To Work

No one appeared to have exact information on the actual 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] Such a group, he thought, should initiate scientific testing of flat, concave and convex surfaces to determine the most efficient wing shapes, possibly in a similar facility, to determine what was needed to invent an aeroplane or aeromotive.

Several attendees at the 1889 Aeronautical Congress had mentioned Louis-Pierre Mouillard and his book *L'Empire de l'Air*, published almost a decade earlier. Chanute purchased a copy in Paris and read it with fascination. To share the information with English speaking investigators, he translated the 280-page book, but regretted that his English was not as colorful as Mouillard's French text. Langley, who had also attended the 1889 congress in Paris and who was now secretary of the Smithsonian, published an abbreviated translation in the *Annual Report of the Smithsonian Institution* for 1892.

In March 1890, Chanute wrote his first letter to Mouillard,[13] living in Egypt. Half a year later, Chanute explained his ideas on manned flight: "I should not even dream of imitating the bird, but I believe it is possible to apply the same principles to obtain a stable equilibrium. The question now is to limit as much as possible any movement of the center of pressure, without decreasing the lifting surface."[14] In his response, Mouillard explained his thoughts: "When the bird is about to turn, the wing tip twists. . . . The feathers obstruct the motion; they stop it, forming a long lever on this point. This causes a variation of motion and a rapid change of direction."[15] Chanute now wondered, could extra drag be applied to one wing to turn the machine in flight? Just like a locomotive banking when going into a curve?

In the late 1880s, with the industrial movement 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, the new 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. Chanute went to Ithaca, N.Y., on May 2, 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."

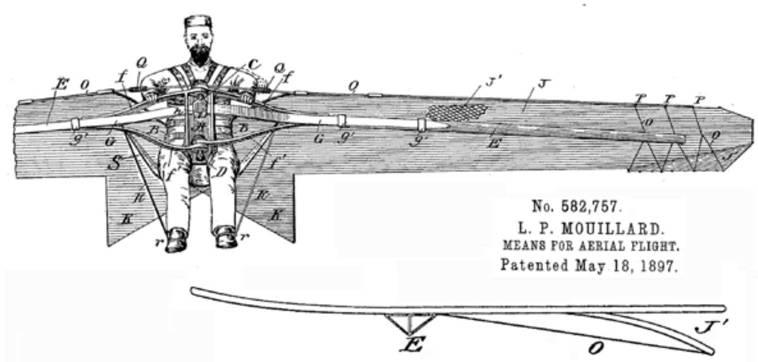
Lecturing on the unconventional topic of aeronautics in an academic surrounding,[16] Chanute selected his words carefully. Going public was a breakthrough for him, but he looked for inventive young minds to supply fresh ideas to help him solve the century-old problem. One of the attending students, 28-year-old 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."[17]

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 published a brief discussion on "Motors for Aerial Machines," but rejected everything else.[18] Chanute 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 U.S., who gladly published the expanded lecture in five installments,[19] simply entitled "Aerial Navigation."

In his influential paper of 1866 the civil engineer Francis Wenham[20] described the mechanics of his flying machine:

> ". . . Two propellers were to be attached, turning on spindles just above the back. They are kept drawn up by a light spring, and pulled down by cords or chains . . . By working this cross-piece with the feet, motion will be communicated to the propellers, and by giving a longer stroke with one foot than the other, a greater extent of motion will be given to the corresponding propeller, thus enabling the machine to turn, just as oars are worked in a rowing boat."

In other words, to turn a flying machine in flight, more thrust was needed to be generated on one side than on the other. Chanute believed that the flying machine could be banked similar to the locomotive going into a curve on a raised track. When he and Mouillard wrote up the claims in their patent,[21] they described the steering of the machine as: "A portion J' of the fabric at the rear of each wing is free from the frame at its outer edge and at the sides. A pull upon one of these handles causes the portion J' to curve downward, and thus catch the air, increasing the resistance upon that side of the apparatus and causing it to turn in that direction . . . For turning in the



Drawing of wing "warping" in U.S. Patent 582,757.

horizontal plane, the resistance on one wing is increased, so that it tends to travel at a less velocity than the other. This is done by warping the apparatus provided for the purpose."

Creating drag worked as an effective brake in a two-dimensional scheme, but banking a flying machine in three dimensions was different. In this patent, neither Chanute nor Mouillard considered the lifting effect, which would turn the machine in the opposite direction of what they intended. It took a few more years to put the turning of an aircraft into reality.

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 mechanical flight and aeronautics. Starting in October 1891 he submitted monthly articles to the *Railroad and Engineering Journal,*[22] using images from the French pamphlet *Histoire des Ballons et des Locomotives Aériennes*[2] and from Emmanuel Dieuaide's *Tableau d'Aviation.*[23] This article series provided detailed information on almost everything known about aeronautics. Chanute also hoped that the presented information would help avoid duplication of failed experiments, or waste energy and funding, and would result in eventually accomplishing mechanical flight.

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 could be employed as motors for flying machines. Chanute theorized, however, 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 hp for an aeroplane with 1000 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."

Forney combined the 27 articles and published them in book format as *Progress in Flying Machines* in April 1894. He had about 500 sets of pages printed; 200 books were bound in the spring of 1894 and the remaining pages were bound in 1899 with a new title page and binding. This book never hit the best-seller list, but it quickly became the definitive publication on the history and current status of flying machines, clearing the field of many uncertainties. 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.[24]

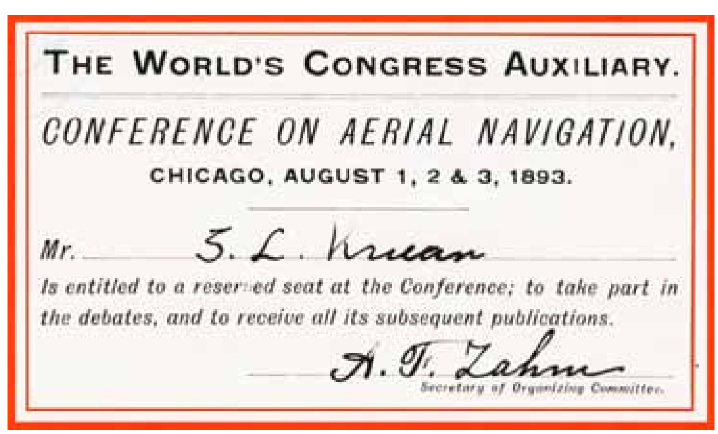
Book Advertisement in the Railroad and Engineering Journal.

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, sound advice and criticism and provided occasional financial support. This conduit was vital for the exchange of ideas as the invention of the airplane evolved. He 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 left the room and tapped their foreheads while exchanging significant glances when the conversation turned to flying machines.[25]

Manned Flight is Possible

The upcoming World's Fair in Chicago was to illustrate the development of transportation via rail, wheel, water and air.[26] Albert F. Zahm, Professor of Mechanical Engineering at Notre Dame, Ind., 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 crackpots 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 "cranks" from disrupting the conference, every person who wished to attend had to purchase in advance a "personal card of admission" for $3, which entitled the bearer to a reserved seat at the conference and to take part in the discussion.

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,[27] but politicians ignored it, just as they had in the past. Meanwhile, people like Chanute, James Means, Samuel Langley and others continued to publicize the idea that manflight was an acceptable science;



A total of 71 admission cards were sold.

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TABLE OF NORMAL AND TANGENTIAL PRESSURES

Deduced by Lilienthal from the diagrams on Plate VI., in his book "Bird-flight as the Basis of the Flying Art."

α Angle.	η Normal.	ϑ Tangential.	α Angle.	η Normal.	ϑ Tangential.
− 9°	0.000	+ 0.070	16°	0.909	− 0.075
− 8°	0.040	+ 0.067	17°	0.915	− 0.073
− 7°	0.080	+ 0.064	18°	0.919	− 0.070
− 6°	0.120	+ 0.060	19°	0.921	− 0.065
− 5°	0.160	+ 0.055	20°	0.922	− 0.059
− 4°	0.200	+ 0.049	21°	0.923	− 0.053
− 3°	0.242	+ 0.043	22°	0.924	− 0.047
− 2°	0.286	+ 0.037	23°	0.924	− 0.041
− 1°	0.332	+ 0.031	24°	0.923	− 0.036
0°	0.381	+ 0.024	25°	0.922	− 0.031
+ 1°	0.434	+ 0.016	26°	0.920	− 0.026
+ 2°	0.489	+ 0.008	27°	0.918	− 0.021
+ 3°	0.546	0.000	28°	0.915	− 0.016
+ 4°	0.600	− 0.007	29°	0.912	− 0.012
+ 5°	0.650	− 0.014	30°	0.910	− 0.008
+ 6°	0.696	− 0.021	32°	0.906	0.000
+ 7°	0.737	− 0.028	35°	0.896	+ 0.010
+ 8°	0.771	− 0.035	40°	0.890	+ 0.016
+ 9°	0.800	− 0.042	45°	0.888	+ 0.020
10°	0.825	− 0.050	50°	0.888	+ 0.023
11°	0.846	− 0.058	55°	0.890	+ 0.026
12°	0.864	− 0.064	60°	0.900	+ 0.028
13°	0.879	− 0.070	70°	0.930	+ 0.030
14°	0.891	− 0.074	80°	0.960	+ 0.015
15°	0.901	− 0.076	90°	1.000	0.000

The Lilienthal table helped pave the way for further development.

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*[28] (Pocketbook of Aeronautics) 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 [drag] 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. This article[29] 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 three wing shapes and test each 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 and prove their theories, but then left Chanute's employment to work for the Smithsonian Institution.

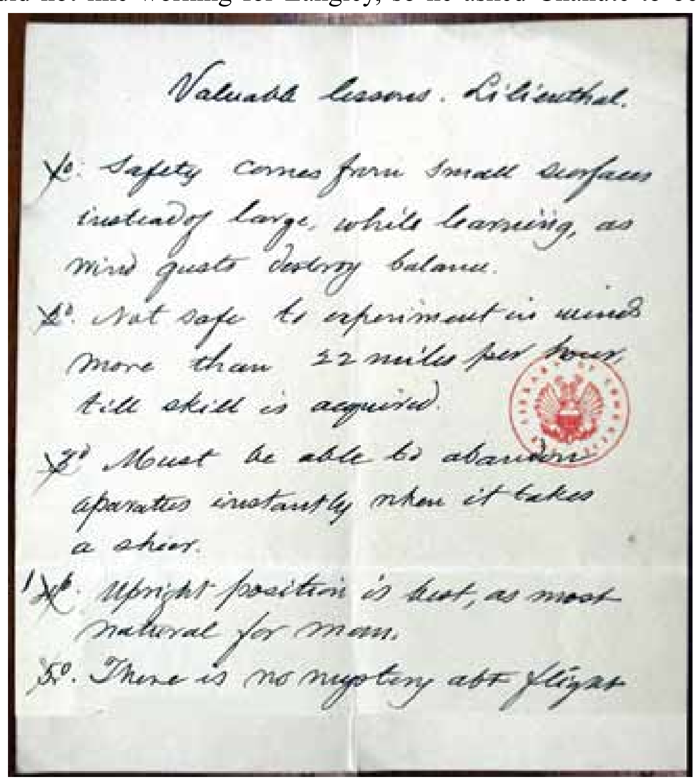
From Theory to Investigating

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 almost 20 different glider models. 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 August 10, 1896, from injuries sustained in a crash of his glider, ending a promising aeronautical career.

Samuel P. Langley succeeded in May 1896 to launch and fly his steam-powered model aircraft, Aerodrome No. 5. The model with a 15-foot wingspan remained in the air for one minute 20 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 manflight.

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 his "soaring machine," but this project was more complicated than either had first anticipated. At about the same time, Augustus Herring did not like working for Langley, so he asked Chanute to be


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 apparatus instantly when it takes a sheer.
4°. Upright position is best, as most natural for man.
5°. There is no mystery abt flight

Chanute's memo on lessons learned after reading write-ups by Otto Lilienthal in 1894 and 1895. (Chanute Papers, LoC)

The southern shore of Lake Michigan, showing the location of Millers and Dune Park, where Chanute and his team performed gliding experiments in 1896 and 1897.

rehired, and the Herring family moved to Chicago in January 1896.

Having studied Lilienthal's American patent[30] in depth, Chanute had submitted his improvements to the Lilienthal glider to the United States Patent Office.[31] He now wanted to incorporate his claims into Herring's Lilienthal-type glider, as they were thought to be essential to achieve longitudinal (today we call this pitch) stability.

Six weeks after Langley's successful launching of his unmanned aerodrome, the excitement began for Chanute's team. On Monday morning, June 22, 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 a.m., arriving at Millers, Ind., 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" beard, 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.

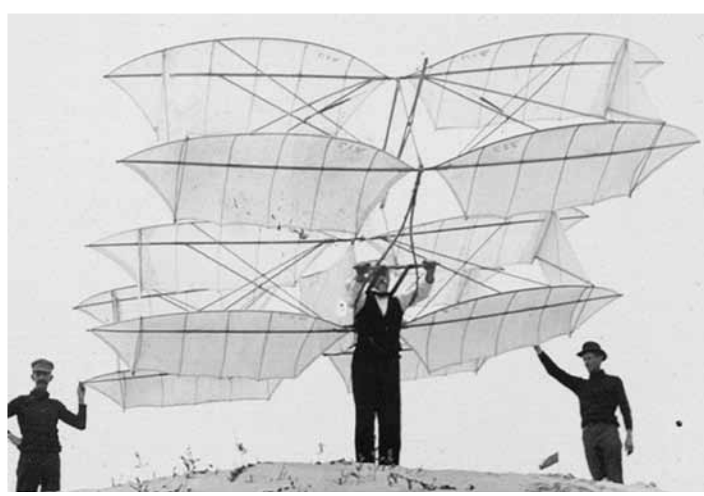
After pitching their tents, the men assembled the Herring/Lilienthal glider first, as Chanute wanted to validate the work done by others and separate fact from error before venturing into the unknown to discover the unanticipated. Herring was the first to launch with his glider into the wind, looking like a huge butterfly with concave wings, slowly settling to the ground.[32] But the Lilienthal-type did not perform as expected, or as Chanute recorded in his notebook, "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 15 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.[33] To make this a true sport, flying had to become much easier and safer.

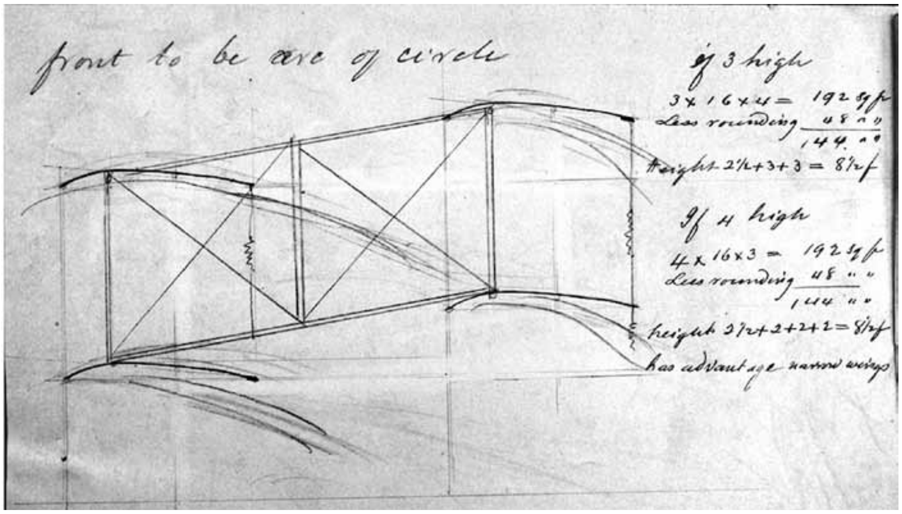

MR. HERRING'S FLIGHT WITH THE IMPROVED LILLIENTHAL SOARING MACHINE.

No good photo exists of the Lilienthal-type in flight, but the newspaper reporter caught the machine in flight with his pen.

From Investigating to Trials

While the eagles and gulls flew effortlessly overhead, demonstrating how flying ought to be done, the men assembled Chanute's "soaring machine." This glider, based on Francis Wenham's multiplane design, had 12 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. He envisioned this soaring machine to glide at angles of three to seven degrees in light breezes and eventually soar in stronger


The Katydid, a multiplane glider that functioned as a flight test model. (Chanute Papers, LoC, wb0039p-13-004)



Studying the flow of the wind over the wings with the help of bits of down feathers, Chanute could figure out how to increase the efficiency of the wing grouping. Chanute Papers, LoC

winds, either in spirals in a 10-mile breeze or in aspiration in a wind blowing at 20 mph. 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.

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 keep track of any changes. Methodically, Chanute now 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.[33] "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."

Slowly, the craft evolved from a ladder kite to an ordinary multiplane glider. The resulting *Katydid,* named after the mid-western grasshopper, could be handled in 20-mph wind and the operator needed to move only two or three inches and not the acrobatic 15 to 18 inches that Herring's Lilienthal-type had required. In a 13-mph breeze, the *Katydid* could glide with its pilot in an angle of descent a little better than one in four.

Chanute's team returned to Chicago on Saturday, July 4, 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.

Chanute's entry in his notebook on July 2, 1896, reads: Found machine quite steady and manageable. The lift was greater and the head resistance apparently less. Took scores of glides. (Chanute Papers, LoC, wb0039p-12-004)

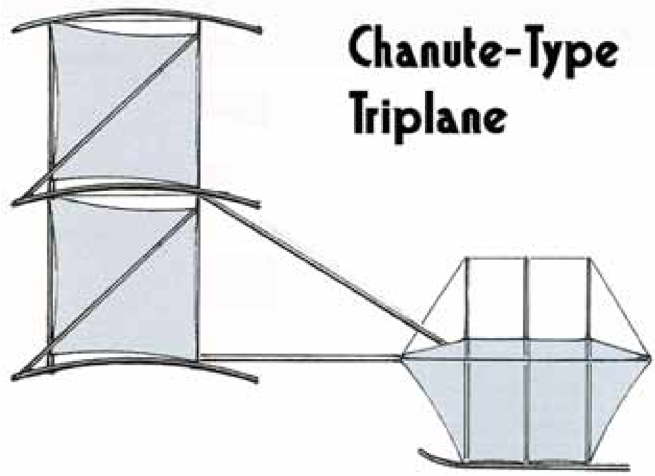
From Triplane to Biplane

Back in Chicago the findings of their flight research with the multiplane glider were evaluated and incorporated into the next design. With the knowledge gained, Chanute 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" [34]. The birds maintain a stable equipoise by instinct, thus he wanted his aircraft to stabilize itself under any wind conditions as well; the pilot should only intervene to change the flight direction. Or simply put, "without assured equilibrium, safety is uncertain; and without a reasonable degree of safety, flight whether for pleasure or for business, is out of the question."[35]

Having learned how to efficiently position the wings of 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 shape of the wing of the soaring birds, Chanute consulted with John B. 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 new "fixed-wing" glider had three superposed surfaces with a 16-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



No photos exist of the triplane; there are only a variety of notes in the Chanute Papers, LoC. (Drawing by Reinhard Keimel)

Sailing along (or "tobogganing on the air") in the biplane. (Chanute Papers, LoC, wb0039p-16-005)

how he determined the wire size: "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."[36] 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.

Chanute's team returned to the dunes along the southern shore of Lake Michigan on August 20, 1896, this time traveling by boat instead of the railroad. The triplane glider was assembled and first flown on August 29; 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."

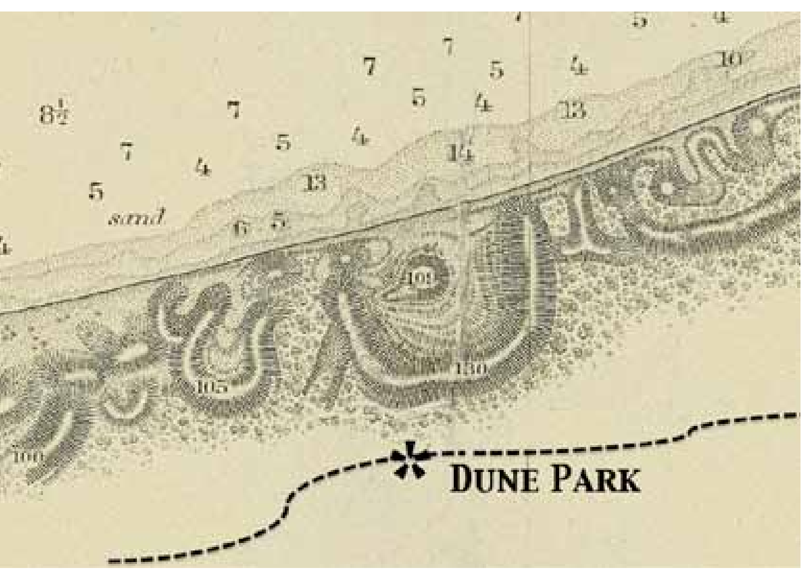
On September 11 steady northerly winds of 25 to 30 mph blew against the dunes, allowing several long flights with a much shallower angle of descent than the glides with no wind on the previous days. The visiting *Chicago Tribune* reporter Henry Bunting reported,

"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 40 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."[37]

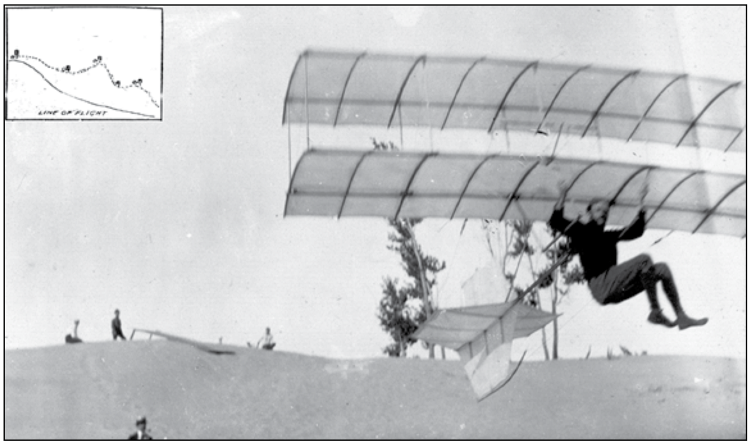
Documenting their findings, Chanute wrote:

> "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 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."

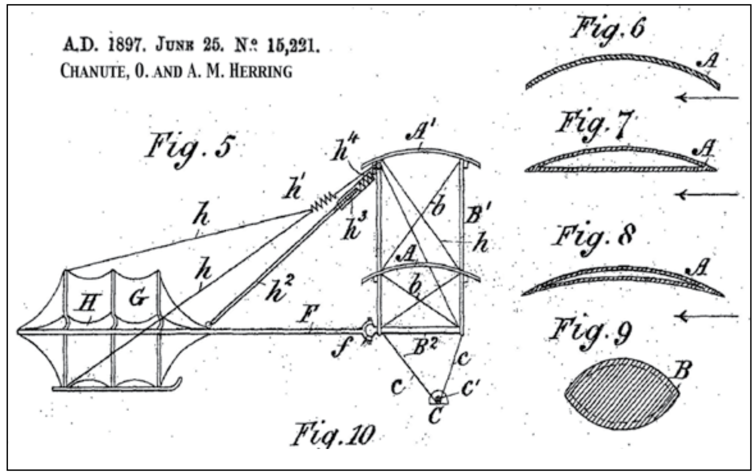
A total of about 330 flights of various length and duration were made in the summer/fall of 1896 by a variety of people, not only by members of Chanute's team. Some of these flights were very short and Chanute called them "jumps", others were longer or "runs" and finally the longest were "glides" or "flights." The longest reported flights were 359 feet and 14



The Dune Park area, cut from an 1894 Coast Guard map of the southern shore of Lake Michigan.



A good start with the biplane. Note the takeoff ramp and the many visitors who came to help but also try the new sport. (Chanute Papers, LoC, wb0039p-29-008)



Drawing of biplane glider from British Patent No.15,221.

seconds by Herring on September 12 (without observers), and 256 feet by Avery and 239 feet by Herring the previous day with everyone in camp watching.

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."[38] 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.[39]

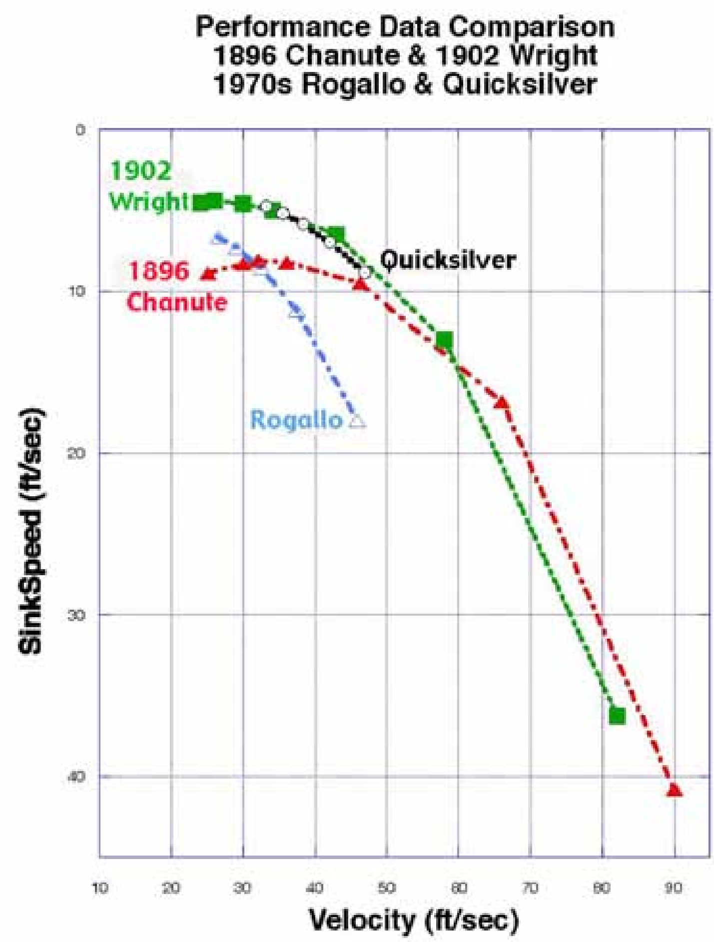
Breakdown of flights made in 1896 by Chanute's team

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

Flying Fliver 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. To make the design known and available to other experimenters, he not only published articles with photos and drawings, but he also wanted it patented. He submitted his claims to his patent lawyer in Washington, who turned it down. So he sent the drawings, as well as Herrings claims for a motorized triplane, to Thomas Moy in England to be patented. The British Patent Office did the rest by distributing the abbreviated patent information around the world.

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



Performance data comparison of the 1896 Chanute-type and the 1902 Wright glider, compared with the 1970s Rogallo and Quicksilver hang gliders. (Data calculation by Albion Bowers) 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. Like most human inventions, the aeroplane 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 an important prototype.[40]

The effect of Chanute's efforts became obvious during the next decade. His practice of working in goal-oriented information-sharing settings became a hallmark of cooperative American aviation development in the early decades of the 20th century. ✈

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The Western Society of Engineers from Chicago, Ill., dedicated this plaque that reads "Octave Chaute, an eminent engineer, father of aviation, made these first successfull flight in heavier-than-air craft from these dunes in 1886. This glacial boulder dedicated to his memory in 1936."

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   The reference to "Darwin's prophecy" refers to lines in a long poem entitled "Botanic Garden" (1791), by Erasmus Darwin

   Soon shall thy arm, unconquer'd Steam! afar
   Drag the slow barge, or drive the rapid car;
   Or on wide-waving wings expanded bear
   The flying-chariot through the fields of air.

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