MECHANICAL FLIGHT.

By J. Emery Harriman, Jr., C. E.

[Read before the Boston Society of Civil Engineers, May 4, 1904.*]

I shall confine my address mostly to flying machines heavier than the air displaced by them, and shall have but little to say about propelled balloons, except at intervals showing some of the most noted experiments, as they are in an entirely different class.

I shall begin by reading a short description of flight written by J. Bell Pettigrew, published in book form in 1874. He writes:

"However paradoxical it may seem, a certain amount of weight is indispensable to flight. Power and weight may be said to reciprocate by blending their peculiar influence to produce this common result.

"In the aërial machine, as far as yet devised, there is no sympathy between the weight to be elevated and the lifting power, while in natural flight the wings and weight of the flying creature act in concert and reciprocate; the wings elevating the body the one instant, the body by its fall elevating the wings the next.

"Weight, assisted by the elastic ligaments or springs which recover all wings in flexion, is to be regarded as the mechanical expedient resorted to by nature in supplementing the efforts of all flying things.

"Without weight, flights would be of short duration, labored and uncertain, and the almost miraculous journeys at present performed by the denizens of the air, impossible.

"Flight may be divided into 2 principal varieties, which represent 2 great sects or schools.

"1st. The balloonist or those who advocate the employment of a machine specifically lighter than air.

"2d. Those who believe that weight is necessary to flight. The second school may be subdivided into—

"A. Those who advocate the employment of rigid inclined planes driven forward in a straight line by revolving planes (aërial screws); and

B. Such as trust for elevation to the vertical flapping of wings.

"To construct a wing which shall elude the air during the up stroke it is necessary to make it valvular, so arranged that the air, when the wing is made to vibrate, opens or separates the valves at

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the beginning of the up stroke, and closes or brings them together at the beginning of the down stroke. Repeated experiment has convinced me that the artificial wing must be thoroughly under control both during the down and up strokes.

"The artificial wave wing can be driven at any speed. It alternately seizes and evades the air so as to extract the maximum of support with the minimum of slip and the minimum of force.

"It supplies a degree of buoying and propelling power which is truly remarkable. It can act upon still air, or it can create and utilize its own currents. The fact that the wing of the insect, bat or bird can be readily imitated and reproduced should inspire the pioneer in aërial navigation with confidence.

"In attempting to produce a flying machine it is not necessarily attempting an impossible thing. Of the many mechanical problems before the world at present, perhaps there is none greater than that of aërial navigation."

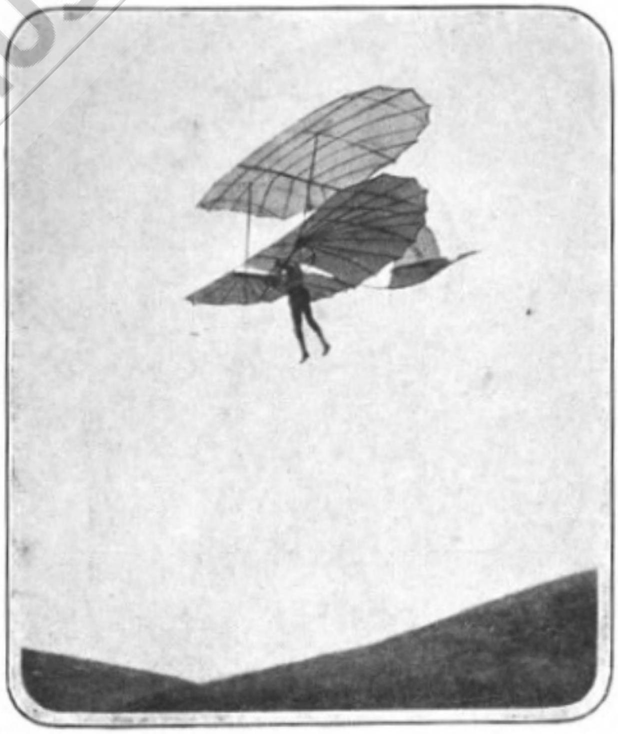
In 1889 Otto Lilienthal, a German engineer, mathematician, ingenious inventor and skillful experimenter, published a book on mechanical flight, and made hundreds of experiments with gliding machines of his own design and make.

He made a number of aëroplane machines, and used gravity for the motive power, starting from high hills and soaring to the plains below. He said that the construction of a flying machine for practical operation in nowise depends upon the discovery of light and powerful motors, as, with an ordinary wind, man's strength is sufficient to work efficiently an appropriate flying apparatus.

In order to operate such an apparatus with the greatest possible economy, it should be based, both in shape and in proportion, upon the wings of large high-flying birds. The framing and spars should be in the front edge of the wings, as far forward as possible, and the wing tips should encounter as little resistance as possible on the up stroke. No amount of motive power will avail unless the machine can rise, sail and come down again without danger of losing its equipoise.

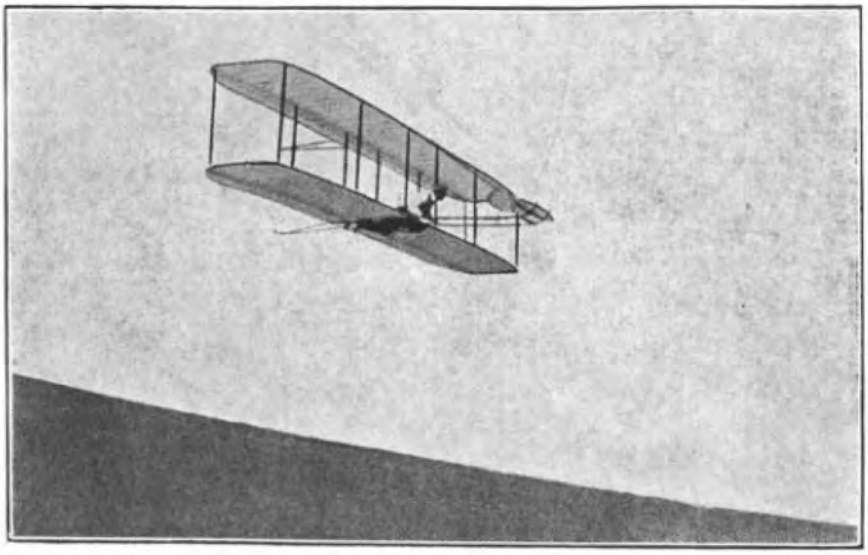
Experiments should be carried on preferably with full-sized machines carrying a man, and arched wings should be used in preference to plane ones. Lilienthal "demonstrated the feasibility of actual practice in the air, without which success is impossible, and in so doing made the greatest contribution to the solution of the flying problem that had ever been made by any one man."

Following Lilienthal's experiments, Mr. Pilcher, an English



Herr Lilienthal's Flying Machine.

THE SOARING MACHINE OF OCTAVE CHANUTE.



THE WRIGHT BROTHERS' GLIDING MACHINE.

engineer, slightly improved the apparatus and made many hundred glides.

Mr. Octave Chanute, of Chicago, past President of the American Society of Civil Engineers, has contributed greatly to the problem of mechanical flight, not only by encouraging writings and lectures, but by building gliding machines and making interesting experiments with the assistance of Mr. A. M. Herring, a civil and mechanical engineer. In his latest article on aërial navigation, published in the *Popular Science Monthly* of March, 1904, Mr. Chanute writes:

"After 4000 or 5000 years with a problem that has impassioned man, a successful flying machine seems to have been produced by the Messrs. Wright."

In 1897, in his address to the Western Society of Engineers, he said that, "As an engineer, approaching the end of his professional career, it seemed an opportune time to devote some of his leisure to the investigation of the laws which must be hereafter observed by other engineers in compassing the navigation of the air." He said he had hitherto abstained from addressing his fellow-engineers on the subject as some might deem it premature; but he had become convinced, not only by investigation, but through practical experiment, that it was not only possible but almost certain that man will eventually be enabled to make his way through and on the air by dynamic means.

Mr. Chanute took up—

1st. The supporting power and resistance of air.

This first problem is the foundation of the whole subject, and, singularly enough, it is only within the last 6 years that it has been settled beyond question what is the true measure of those properties of air when meeting a surface at an oblique angle of incidence.

2d. The motor: its character and its energy.

This second problem, now nearly solved, was, until 5 years ago, thought to be still more difficult than the obtaining of supporting power from the air. Great advances have been made with petroleum motors, which possess the great merit of dispensing with a boiler, so that, for the first time, the realization of a sufficiently light motor for a dynamic flying machine seems to be within sight.

3d. The instrument for obtaining propulsion.

Mr. Maxim and Professor Langley have made experiments to determine the best form, speed and pitch of the screw to obtain thrust from the air, and have materially improved that instrument which, to reason from analogy in land and water transportation, seems likely to prove the best device; but both Mr. Hargrave and Mr. Lilienthal have obtained very favorable results with the flapping pinion, which requires no intervening machinery to change the reciprocating action of a piston into a rotary motion, and it seems perhaps possible that success in artificial flight may be obtained by either or both devices.

4th. The form and kind of the apparatus.

(1) Wings to sustain and propel. (2) Rotating screws to lift and propel. (3) Aëroplanes or aërocurves, to consist of fixed surfaces driven by some kind of propelling instrument.

5th. The extent of the sustaining surfaces.

The extent of the sustaining surfaces required to support the weight of a man has in the past caused active controversy and gathering of data. In point of fact, the amount required depends upon the speed of the creature's flight.

6th. The material and texture of the apparatus.

. For a beginning, wood will do very well. It is a fact realized by few engineers that the best woods, so long as they remain undecayed, are actually stronger in proportion to their weight than the ordinary grades of steel. Wood is easily and cheaply procured and shaped, and whatever success has hitherto been had in gliding flight has been accomplished with wooden frames covered with textile fabrics.

7th. The maintenance of the equilibrium.

The first requisite for this is that the center of gravity shall constantly be in a vertical line with the center of pressure, and unfortunately the latter is almost constantly varying with the relative wind, with the speed and with the angle of incidence. Until automatic equilibrium is secured and safety is thereby insured under all circumstances, it will be exceedingly dangerous to apply a motor and a propeller.

8th. The guidance in any desired direction.

It has been generally supposed that this would be best effected by horizontal and vertical rudders, but the experiments of Lilienthal and others have shown that slight changes in the position of the center of gravity are more immediate and effective.

9th. Starting up under all conditions.

The solution of the question as to the best methods of starting away from the ground is likely to be one of the last to be practically worked out.

10th. Alighting safely anywhere.

This is the problem which always produces a smile upon its bare enunciation, probably in remembrance of that little experiment of Darius Green. It may be said to be yet unsolved for the dynamic machine of the future, and yet both Lilienthal's experiments and others showed this problem to be very easy of solution with a gliding machine by simply making use of increased air resistance at greater angles of incidence to stop the headway before alighting on the ground.

Mr. Chanute has carefully prepared his reports of all experiments and illustrated them with more than 30 photographic half-tone pictures.

Mr. Hiram Maxim, the inventor of the Maxim gun, an American in England, Professor Langley of the Smithsonian Institution, Mr. Hargrave in New South Wales and Mr. Lilienthal in Germany in 1888, all at about the same time took up this study of mechanical flight.

Mr. Maxim experimented at a cost of more than $100,000, and constructed an enormous aëroplane weighing more than 8000 pounds with the men, water and fuel on board. It was driven ahead by 2 large screw propellers, 17 feet 10 inches in diameter and 5 feet wide at the tip of the blade. The whole machine rested on wheels on a track of 8-foot gauge, with an upper track to hold the machine down while making experiments under speed. The framework was of strong, thin steel tubes, stayed with steel wires, and the horizontal shape of the surface plane was almost an octagon, covered with varnished balloon material, with a smaller, narrow superposed plane. The angle of the aëroplane was 1 in 8, as Mr. Maxim wished to get as great a lifting power as possible on the comparatively short track with relatively low speed. When the steam pressure reached 363 pounds per square inch and the machine was driven forward, it rose from the lower track and passed upward to the guard track and even tore up about 100 feet of the guard rails before the machine was stopped. Mr. Maxim writes that when, on the first occasion, his aërial apparatus lifted itself clear of the tracks by the energy of its own engines, he felt that the ultimate success of the flying machine was assured.

Professor Langley was the first one to successfully demonstrate, on May 16, 1896, in actual flight, without an operator, a mechanical model flying machine. After years of careful study and experiment he has tabulated most important information that will be of value to all who follow in his line. He made the remarkable and, to the engineer, paradoxical statement that, in such aërial navigation as was there shown to be possible under certain definite conditions, the power required would in theory diminish indefinitely as the speed increased, and that it would actually diminish in practice up to a certain limit. His experiments have been made in such a thorough, scientific and theoretical way, with every minute detail worked out for every separate part, that it has cost a large sum of money for preparation before a full-sized machine was even constructed; but this expenditure by the Government should not be begrudged, for he has published and fully illustrated all his experiments, which are invaluable to those who will follow in his line.

Closely following Professor Langley's latest experiments, is the remarkably successful demonstration, by Messrs. Wilber and Orville Wright, engineers, of Dayton, Ohio, with their aëroplane. For more than 4 years they have been experimenting with a gliding machine in the same manner as Mr. Chanute and Mr. Herring, and have devoted the most of that time to learning the art of balancing and guiding the machine in soaring flight. They made a number of original departures from the methods of other experimenters, in the first place by assuming a horizontal position, really lying face downward on the lower plane of the machine, and next by transferring the guiding rudder from the back to the front of the machine. To give a clear description of the Wright brothers' machine, and to explain the experiments made by them, would require the reading to you of the able reports made by Mr. Wilber Wright before the Western Society of Engineers, where he was presented by the President, Mr. Octave Chanute, on September 18, 1901, and again on June 24, 1903. These reports are well illustrated by photographic views, and are valuable text-books in the art of flying.

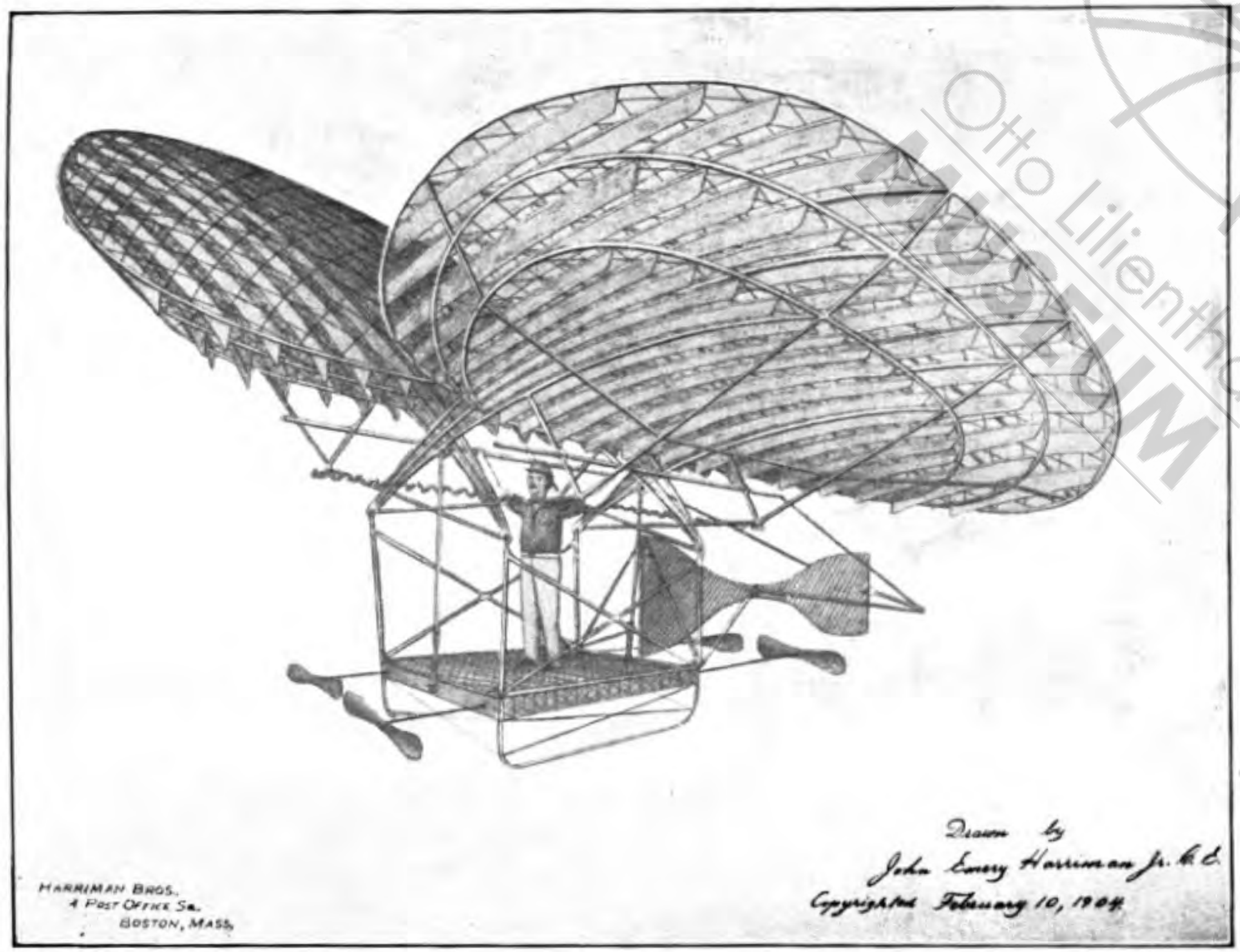
I will read an extract from Mr. Wilber Wright's report, published in the *Independent,* February 4th, this year, which describes their most recent and very successful attempt at flying.

"While carrying on these experiments our power machine was under construction. In dimensions it measures a little over 40 feet from tip to tip of the wings, of which there are a pair. Its length, fore and aft, to use a nautical phrase, is about 20 feet; and the weight, including that of the operator, as well as the engine and other machinery, is slightly over 700 pounds. We designed the machine to be driven by a pair of aërial screw propellers placed just behind the main wings. One of the propellers was set to revolve vertically and intended to give a forward motion, while the other, underneath the machine and revolving horizontally, was to assist in sustaining it in the air. We decided to use a gasoline motor for power, and constructed one of the 4-cycle type, which, revolving at a speed of 1200 revolutions a minute, would develop 16 brake horse power. It was provided with cylinders of 4-inch diameter, having a 4-inch stroke and intended to consume between 9 and 10 pounds of gasoline an hour. The weight of the engine, including the wheel, is 152 pounds.

"We had calculated that the amount of mechanical power provided would be sufficient to maintain the machine in the air, as well as to propel it, the calculation being the result of gliding experiments which showed that when the wind was blowing at 18 miles an hour, the power consumed in operation was equal to 1½ horse power, while with a wind of 25 miles an hour it represented 2 horse power, being capable of sustaining a weight of 160 pounds per horse power at the 18-mile rate. After the motor device was completed, 2 flights were made by my brother and 2 by myself on December 17th last. The apparatus had been placed on a single-rail track, built on the level, the track supporting it at a height of 8 inches from the ground. It was moved along the rail by the motor, and, after running about 40 feet, ascended into the air. The first flight covered but a short distance. Upon each successive attempt, however, the distance was increased, until at the last trial the machine flew a distance of a little over a half mile through the air by actual measurement. We decided that the flight ended here, because the operator touched a slight hummock of sand by turning the rudder too far in attempting to go nearer the surface. The experiment, however, showed that the machine possessed sufficient power to remain suspended longer if desired. According to the time taken of each flight, a speed varying from 30 to 35 miles an hour was attained in the air. We should have postponed these trials until the coming season, but for the fact that we wished to satisfy ourselves whether the machine had sufficient power to fly, sufficient strength to withstand the shock of landing and sufficient capacity to control. Winter had already set in when the last trials were made, but these facts were definitely established, and we know that the age of the flying machine has come at last."

It so happens that the machines and experiments that I have thus far mentioned were all made by civil or mechanical engineers of thorough technical and practical training, and in each and every instance they made a study of the problem before making experiments, which so well demonstrated their belief in mechanical flight that without hesitancy they have publicly proclaimed and published their conclusions without fears as to the final results.

Perhaps, before going further in describing what is being done in preparation for the aëronautic competition at St. Louis this summer, it would be fair for me to tell how I have become interested in the subject. In the first place, I have had the opportunity while engaged in engineering to watch and study the flight of the American vulture, pelican, flamingo and sea fowl on the coast of Texas, hundreds of half-tamed sea gulls at the docks of Seattle, the broad-winged hawks near Lake Champlain and the large fishhawks among the islands of Penobscot Bay, Me., and in all instances I have been greatly impressed with the ease and grace of the slow flapping of the wings and the ability to soar through space. I have noticed particularly that at the same time with the downward flap of the wings there seemed to be a voluntary rise of the body of the bird, and as the wings were raised again the body seemed to drop slightly. It was this movement that inspired me to try to design a machine wherein the weight and muscles of the operator should assist in opening the wings on the upward stroke, and the release of that weight and power, by his jumping slightly and transferring it to the wings, should assist in the downward stroke, and my study resulted in the design here shown in perspective. This movement alone, to my mind, would reduce to a minimum the extra mechanical power necessary to flap the wings; and it is one of the principal points of my *design* here open to your inspection. It was shortly after this, while studying what had been done by others, that I found, in the library, what to me seems one of the best descriptions of flight published, namely, "Animal Locomotion and Aëronautics," by J. Bell Pettigrew, F.R.S.E., which I have already mentioned as being published in 1874; and it was the last sentence I have already repeated that gave me the assurance to hold to my belief, namely, "In the aërial machine, as far as yet devised, there is no sympathy between the weight to be elevated and the lifting power, while in natural flight the wings and weight of the flying creature act in concert and reciprocate; the wings elevating the body the one instant, the body by its fall elevating the wings the next." The downward flap of the wings would be assisted by springs underneath, of a tension about equal to the balanced weight of the body of the machine and operator. Next, in the design of the wings I would form double trusses, to pivot and cross each other, with the car suspended from the overlapping interior ends, which would have a tendency to raise the outer ends of the wings. The edges or circumference of the wings would be connected with the trusses and all would be held together by cross-cord bracing. From this network bracing I would suspend a series of parallel flaps that would close as the wings moved downward and open as the wings moved upward. I would use 2 or 3 wings on each side, one above the other, with a spread, when open, of about 36 feet from tip to tip. The length, from front to back of wing, would be about 18 feet, but



HARRIMAN'S AËROMOBILE.

it would not be entirely covered with the hanging flaps, as I would leave a space between the front and back part to increase the stability and safety of construction. To my mind, it would steady the machine.

I would follow the design of Wright and Chanute in making the wings convex on the upper side and concave below, with a curve in height equal to about one-ninth of the distance from the front edge. I would first try a gasoline engine of about 6 horse power to raise and lower these wings, and would use another engine of about 6 horse power to revolve propellers in front and back of the machine for pulling and pushing it ahead. I cannot believe otherwise than that a valvular wave wing will prove much more efficient than a horizontal revolving propeller in raising the machine, but I should not count on the flapping of the wings to assist very much in the forward motion, but would apply vertical propellers as already described. I would also attach an overhead center wing or canopy to act as a parachute in holding the body of the machine up while the wings are ascending. By this design the weight of operator, car and motive power would be in about the center of the machine and quite a little below the center of gravity, making the machine act as a parachute in case of accident to the propelling mechanism. The weight of this entire machine should not exceed 600 pounds, including the operator, and the cost should not exceed that of an automobile, say $2500.

I believe in flexible wings rather than the rigid aëroplane, as it can better adapt its surfaces to the variable wind pressures. After good headway was once gained there would be no need of further flapping, as the vertical propellers would force the machine through and on the air the same as a rigid machine. The Chanute, Wright and Lilienthal machines slowly glided downward through the air without motive power on a grade of about 15 per cent. It is therefore shown that in every 100 feet traveled, at even a slow rate, it is only necessary to gain 15 feet in order to maintain a horizontal line of travel, while under speed the drop per 100 to be overcome is a mere trifle, and in fact, by the proper inclination of the machine, a rise may be made. The rise and fall of the machine are directed by the operator's changing his position forward or backward, and the turn in direction is made by his shifting his weight to the right or left.

It seems to me that the problem of the mechanical flying machine has already been sufficiently solved and demonstrated to warrant immediate attention to it as a legitimate proposition for progressive business men. There is no more alluring and universally attractive commercial enterprise before the public to-day for promotion, and when people are brought to realize and believe that this wonderful feat has truly been successfully done here in our own country first, by two conservative Americans, the Wright brothers, of Dayton, Ohio, they will wonder why this problem had not been properly attempted before; realize, from what has already been demonstrated at a cost of less than $2500 for 1 machine, and from what will be seen again by the public in a few short months at St. Louis, that the very first attempt at operating an aërocurve or aëroplane flying machine with modern mechanical motive power attached, bearing an operator, succeeded! Not such a wonderful feat after all when viewed from a mechanical standpoint; no unseen parts or movements, no intricate mechanism, no delusion, but reality.

As soon as the public is relieved of its skepticism and the individual investor is given an opportunity to see and know that mechanical flight is not an idle dream or cranky notion, then those who blindly undertake its imitation, regardless of future investigation or knowledge, will possibly make better or worse attempts at reproduction than the true investigators have made in development. It is a problem also open to those who can afford, and who believe in, scientific research and process, regardless of the pecuniary return that may be derived from the successful use and manufacture of the machine. When such men as Prof. Elihu Thomson, Alexander Graham Bell, Emile Berliner, Hiram Maxim, Langley, Chanute and other well-known scientific men give this problem their serious study and attention, with the indorsement of practical men like Mr. Munn, of the *Scientific American;* Colonel Church, of the *Army and Naval Journal;* Mr. Merrill, of the New York *World;* Mr. Brisbane, of the New York *American;* Mr. Walker, of the *Cosmopolitan;* Charles Francis Adams and other well-known Americans, does it not seem somewhat unwise for the non-investigator and non-believer to criticise these endeavors?

One of the greatest events and attractions that the world ever knew will be the aëronautic competition at the St. Louis Fair, open from the first day of June to the first day of October, over an L-shaped track some 30 miles in circuit, for a capital prize of $100,000 and $50,000 in minor prizes. The course will simply be marked out by 3 captive balloons.

Unlike the railroad, the thoroughfare, the open plain, the river, the lake or the ocean channel, the airship or aeromobile will not be confined to grades and alignment. For the flying machine there will never be expensive rights of way to build, protect and maintain, no regular confined channel to follow, buoy, light and map. The direction and elevation above surface are free from obstruction, no matter which way one may travel above sea or land. The air is the only universal highway that leads anywhere and everywhere. It connects all nations, seas and lands alike, without break or obstruction, day or night, and the elemental changes will not be many or so difficult to overcome as those on land or water.

The cost of evolution and construction of the flying machine will never be as great as that of the steamboat, steam engine or electric car or the more recent automobile, and in the near future the flying machine should be a familiar sight.