AERONAUTICS.

UNDER this heading we shall hereafter publish all matter relating to the interesting subject of Aerial Navigation, a branch of engineering which is rapidly increasing in general interest. Mr. O. Chanute, C.E., of Chicago, has consented to act as Associate Editor for this department, and will be a frequent contributor to it.

Readers of this department are requested to send the names and addresses of persons interested in the subject of Aeronautics to the publisher of THE AMERICAN ENGINEER.

WHY IS ARTIFICIAL FLIGHT SO DIFFICULT OF INVENTION?

BY OTTO LILIENTHAL.*

IT is indeed difficult for man to flit through the realm of air with the freedom of a bird; but the longing to do so will allow us no rest. A single large bird circling over our head will renew in us the wish to soar like it in the firmament.

The mechanical instinct of even the average man is sufficient to perceive that we need but to find the right key to unlock for our use an entirely new portal of world-wide communication. Do we not see with what calm, with what complete assurance and wonderfully simple manœuvres yonder bird is gliding through the air? Can it be that man will never be able to accomplish as much?—man, with all his boasted intelligence and with all the mechanical aids that have enabled him to build truly marvellous works! And still it is difficult—I may say exceedingly difficult—to repeat even approximately what nature performs so easily. How many vain efforts have been made to imitate the bird! This, too, now that science has seriously taken up this question; that the phenomena of natural flight have been dissected, anatomically and mechanically, optically and by instantaneous photographs, as well as graphically by electric records. Now, at last, we have progressed so far that the bird cannot mislead us as to the theory, but in practice "he has the laugh on us." As soon as we try to utilize our dearly bought wisdom in actual flight, our lack of skill is painfully displayed; the swallows fly around our heads and twitter their derision. There is probably no other branch of engineering in which it is so difficult to find the right application of our theories in actual practice.

To-day we know very well what supports the flying bird; his wing cleaves the air at great speed, and by the slender curve of its profile compels the necessary sustaining reaction, even in this thin medium. The wind which passes under the widespread sail-surfaces of the bird undergoes a gentle deviation on the concave lower surface of the wing, which results in a sufficient "lift" when the wind is strong enough. The beating of the wing complements what the sail action alone does not accomplish.

To the untrained observer, it is true, when he sees the bird in flight, the movements of the wings seem to be simple up-and-down motions; but the aviator combines the wing beats with the effect of the velocity of flight and the movement of the air, and concludes that even in rowing flight, especially for the larger birds, the carrying surfaces cut the air at a very acute angle, and that in rapid forward flight even a gentle depression of the wings produces much carrying power with little expenditure of energy.

This, therefore, is the action to imitate, this rapid forward motion, with slow beating of the wing—at least, this is what nature teaches us; but it is only in case that the process is carried on with absolute correctness that we may hope to fly in this way. If anything be omitted or incorrectly done, the whole undertaking will fail.

Whether this direct imitation of natural flight is one way out of many which will lead us to the goal, or whether it is the only way, is to-day still a mooted question; many aviators, for instance, consider the wing motion of birds too difficult to imitate mechanically, and they dislike giving up for aerial propulsion the screw propeller, which has been found so useful in the water. On one point, however, they are agreed, and that is that we must fly at high speed if we are to fly at all, and this requirement is a dangerful difficulty in the invention of artificial flight.

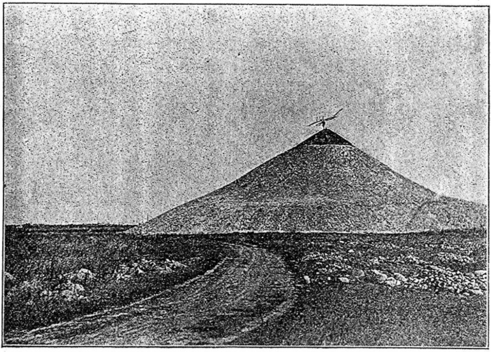

Fig. 1.

It is universally admitted to-day that man will not be able to rise vertically in calm air from a position of rest; no more can the large birds do so, because the expenditure of energy must be enormous. Designers of flying machines, for this reason, now arrange their apparatus so as to begin to rise with a considerable horizontal motion.

Although most projects of the kind are based upon the principle of bird-flight—*i.e.*, the supporting power is obtained by sail-surfaces rapidly moved forward—still the methods of reproducing natural flight by mechanical means are as various as the aviators who undertake the experiments, each man going his own way; but all these separate ways yet lead to one and the same reef, on which the conception and often the ingenious vessel itself is wrecked before it can be utilized for the intended purposes. Indeed they rarely, without breaking the machine, get beyond the first trial, which usually results in the failure to rise into the air at all, or at best to get back to the earth very quickly.

What it means to be whizzing through the air with the velocity of an express train, and then to come back to the ground without danger and without breaking the apparatus, it is not difficult to conceive. If this trick is to be done with a large, heavy, and complicated machine, the prospect of alighting

* Translated from *Prometheus*, No. 261, Berlin.

safely is, of course, much less. It seems really preposterous to count on success in the first trials with such complicated machinery; for this reason the reviewer in No. 259 of *Prometheus* is quite right in his statement that, by experimenting with large machines, the expense of the tuition, which we must surely pay before we learn how to fly, is uselessly increased. Maxim's flying machine, the one alluded to in the above-mentioned review, has cost a very large sum of money, and this distinguished inventor deserves high praise for having devoted so much to aviation, the hitherto Cinderella of engineering science; but, after all, the result of his labors has only been to show us "how not to do it."

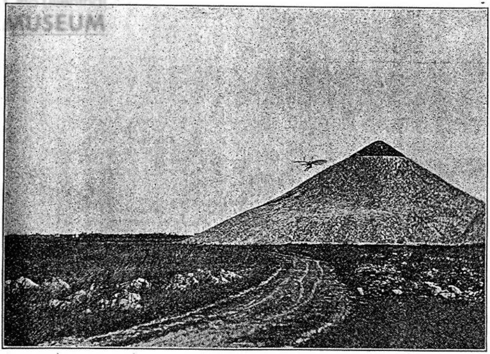

Fig. 2.

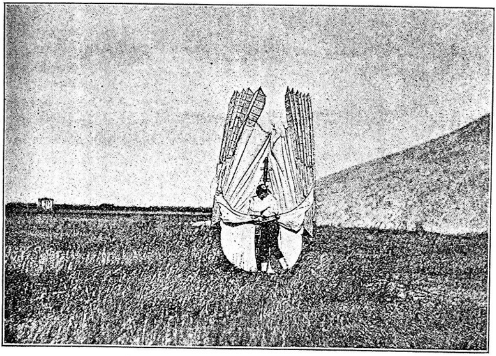

Fig. 3.

This celebrated example may suffice to demonstrate that the most ingenious machinery, even when combined with powerful and very light motors, will not alone solve this intricate problem. Maxim's experiments also prove the truth of another view, which I have alluded to at every opportunity: that, in point of fact, the real destroyer of this machine, weighing 8,000 lbs., was a gentle wind gust, which, in consequence of the enormously large wind surfaces, produced a very great force. The machine could not fail coming to grief, and it will invariably come to grief whenever it is used even in a moderate wind.

Now, which one of all the inventors of such apparatus has the proper conception of the mercilessness of the wind toward all flying machines? This brings up a new difficulty in the invention of artificial flight. I myself have often enough been the plaything of the wind, when I was taken unawares during my experiments by wind gusts; suddenly I was raised the height of a house and tossed back and forth, so that I was breathless until I got used to the sensation. In such experiments one cannot fail to become an air-gymnast in the boldest sense of the word, and I may therefore be permitted to express my opinions on the action of the wind on aeroplanes, and on the best way of counteracting its destructive force.

Herr *Anschütz*, on September 14th of this year (1894), availed himself of an opportunity of taking some photographs of my exercises in windy weather. The illustrations, figs. 5 and 6, reproduced from his instantaneous views, show what gymnastic feats are necessary to keep from being thrown from the saddle in such a squally ride through the air, and to bring back, furthermore, the flying outfit safely to mother earth. These factors cannot possibly be neglected by any one who tries to direct an aerial vehicle through moving air.

If we could not convince ourselves daily how easily and safely birds dart about in the air and command the wind, we might really despair of the invention of artificial flight. But is there any real prospect that we will attain to their skill? What are the real ultimate aims of aviation? To what degree of perfection will it ever be possible to develop human flight? Yes to *develop*, for that is the correct expression, and development is the correct line of thought, by following which we may achieve success in aviation.

No one can foresee to-day how far man will be able to educate himself in flying, because hitherto much too little work has been done in actual practice. Even though, here and there, some scheme may have been actually carried out, and then wrecked on the above-mentioned rock, yet this means very little for the development of dynamic flight. As to the rest, there is a good deal of theorizing, which also does very little good in the present state of the art.

As far as the theory of flight is concerned, we are to-day not at all badly off. Since we have been enlightened as to the air resistance under the bird's wing and the property of its curved section in economizing energy, we can explain quite clearly all the phenomena of natural flight. What we must now begin to develop *ab initio* is actual practice in flight. The difficulties that confront us now are of a purely practical nature, but they are greater than they seem to be at first blush. We must make a special study of these practical difficulties, we must devise methods of investigating them thoroughly in order to counteract them successfully.

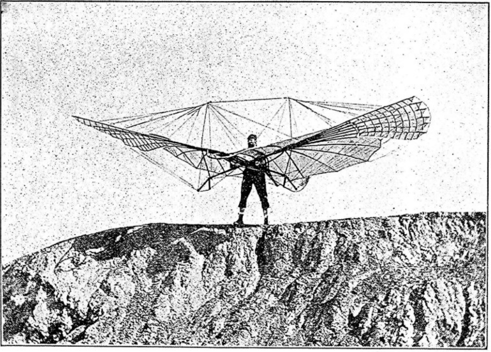

Fig. 4.

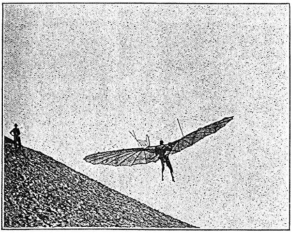

Fig. 5.

Only in this way will we be able to sow the right seed in this now unproducing field.

No matter how primitively it may begin, the method which may lead us to real flight must be capable of development. For this reason the experiments which we make must give us an opportunity of actually flying through the air, even if it be to a limited extent. In this way we will gather experience as to stability in flight, as to the action of the wind, and as to safe alighting: and thus, by constant improvement, gradually come closer to continued flight.

This consummation cannot be violently brought about. It is just because the inventors of flying machines usually expect too great immediate results from their apparatus that the actual achievements are so small. The remaining in the air without a balloon, and cruising about through the atmosphere, is a field of work so novel that we will find our bearings therein only by degrees. Whoever neglects the idea of a healthy development of the science by constantly increasing our experience on the stability and safety of movement in the air, will never accomplish anything in this field.

The methods which I have proposed and practised, in order that, beginning with short flights, I might extend my journeys to greater distances, are known to the readers of *Prometheus*,* from my articles in No. 205 and No. 220 of this journal. I will, therefore, only mention briefly at present my further experiments.

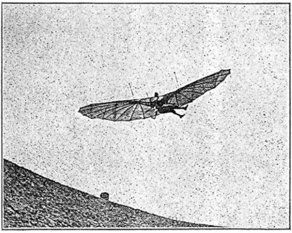

Fig. 6.

* A German paper in which the original of this article was published.

After I had definitely ascertained by my trials that gliding flight is feasible from elevated points, with quite a simple apparatus and in moderate winds, there were two further problems to be attacked. In the first place, this sailing exercise must be extended to stronger winds, so as, if possible, to reach the continued soaring which we so greatly admire in birds; and, in the second place, we must endeavor to complement simple sailing flight by dynamic means, so as gradually to reach a continued flight, even when the air is calmer.

For this purpose it was necessary to have a proper flying-off point near Berlin. I have now constructed such a point, by

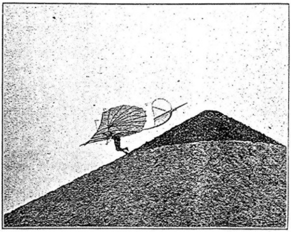

Fig. 7.

building an artificial conical hill, 50 ft. in height, in Gross-Lichterfelde, to the east of the Anhalt Railway. The shape of this hill, and the manner in which it is used, are shown in figs. 1 and 2. Under the top of the hill, which is sodded over, there is a timbered chamber, accessible from the rear, in which the apparatus is stored.

As shown in fig. 7, a run is taken to the edge of the sodding in performing the exercises. Fig. 8 shows the instant of landing, when the sail-surfaces are tipped up to the front, in order to check the velocity of the flight.

An apparatus with an attachment arranged for rowing flight has also been actually tested. Figs. 3 and 4 show this apparatus both when folded and when spread out to its full extent.

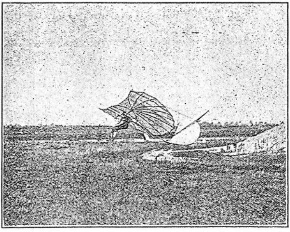

Fig. 8

The distance between wing-tips is 26 ft. 3 in. The flapping motion of the wings is produced by a motor driven by compressed carbonic acid gas. Except for the addition of the rowing device, this apparatus is built quite like my former apparatus. A pressure with a finger starts the flapping of the wings, and as to the rest, the handling of this apparatus is the same as that of the simpler form. Nevertheless, my first cautious trials proved to me that if I had thrown myself into the air with flapping wings, without further precautions, the machine would probably have reached the bottom in the condition of a wreck. There are always new, unexpected features, and a single disastrous landing will ruin the whole machine. Here, again, we are reminded that we must not make too great demands upon the machine at first. I had, therefore, to content myself at first with using this larger and heavier machine, which weighs 88 lbs., or twice as much as my simple sailing outfit, for initial plain gliding. Thus I first practised alighting safely, and now, after getting thus far, I permit myself to begin beating the wings cautiously in actual flight.

There may, of course, be other lines in which artificial human flight may be developed logically. Similar problems will, however, have to be solved in any case before this difficult task is accomplished. Thus, for instance, much energy is being devoted to the question of regulating the flight *mechanically*, so that the equilibrium may not be dependent upon the skill of the operator. We can only hope that this important, although extremely difficult, undertaking may succeed, for then the problem of aviation would be much simplified.

Whatever be the path adopted, progress can only be expected when the experiments made admit of useful observations concerning the phenomena pertaining to a body flying free through the air. There are many entirely new conditions to be considered which do not confront us in other branches of engineering, such as safe and stable flight against all the irregularities of the wind, and the alighting without risk when flying dynamically. These are points on which very little actual experience is at hand, and yet these will be found to be the very essence of practical aviation. This feature will assuredly make more difficult the solution of the problem of artificial flight, but it does not by any means make it impossible. As soon as the conviction becomes general that investigation is needed in this direction, the force now scattered in all directions will become concentrated at the right point, and thus perform efficient service in steadily developing free flight.

MAKING BALLOONS.

A correspondent of the *English Mechanic* gives the following description of the process of manufacture of balloons, which may interest some of our aeronautical readers:

"In making passenger balloons, the silk is, first of all, cut into strips and sewn together. The globe form is then partially filled with air and varnished several times; also tested with air inside and a covering of water outside. If the silk is leaky, bubbles appear in the water. A valve is fitted to the top of the balloon to allow the gas to escape. The valve rope passes right through the center of the balloon to the car beneath. Strong network encompasses the silk when it is filled, and is attached to a hoop, from which the car is suspended. Coal gas lifts 40 lbs. per 1,000 cub. ft.; hydrogen gas lifts 70 lbs. per 1,000 cub. ft. The smallest balloon for passengers is the 12,000 cub. ft. Its weight complete is 280 lbs., and the gas will lift 12 times 40 lbs. = 480 lbs., so that when inflated the balloon has an ascending power of 280 lbs., equal to a man of 150 lbs. and 50 lbs. of sand. Weight of balloon, 280 lbs.; of man, 150 lbs.; of sand, 50 lbs.; total weight, 480 lbs."

Hargrave's Experiments.—Mr. Lawrence Hargrave, of New South Wales, after having built some 18 models of flying machines, all of which fly, is understood to be preparing to build a full-sized apparatus capable of sustaining his weight.

He has lately experimented with a gliding apparatus, based on the same general principle as Lilienthal's, but provided with four wings set at a diedral angle instead of two wings. The bearing surface was 150 sq. ft., and the weight 25 lbs. This did not prove a success; the machine was flabby and unhandy, and turned over with the operator, who then resumed his labors upon his "cellular kites," which were illustrated in Aeronautics.

He now has one of these which flies to windward of its starting-point. Upon the string being tied to a stake in the ground, and the kite raised, it first ascends a certain height, then advances into the wind while the string blows back into a deep *bight*, upon which the kite descends, and comes down to the ground at a point between the stake and the original point of raising, thus performing a feat somewhat like "aspiration."

The construction of the cellular kite has also been simplified, so that it can be readily folded and carried about when of large size.

The last advices from Mr. Hargrave were dated September 23, 1894, which is about the opening of spring in the southern hemisphere, so that we may expect to hear of interesting experiments tried by him during the coming Australian summer.