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PRACTICAL EXPERIMENTS FOR THE DEVELOPMENT OF HUMAN FLIGHT

BY OTTO LILIENTHAL.

Whoever has followed with attention the technical treaties on flying will have become convinced that human flight cannot be brought about by one single invention, but is proceeding toward its perfection by a gradual development; for only those trials have met with success which correspond with such a development. Formerly men sought at construct flying machines in a complete form, at once capable of solving the problem, but gradually the conviction came that our physical and technical knowledge and our practical experiences were by far insufficient to overcome a mechanical task of such magnitude without more preliminaries.

Those proceeding on this basis therefore applied themselves, not to the problem of flying as a whole, but rather divided it into its elements, and sought first to bring a clear understanding into said elements which should form the basis of final success. For example, take the laws of atmospheric resistance, upon which all flying depends, and regarding which, until very recent years, the greatest uncertainty has existed; these have now been defined to such an extent that the different phases of flight can be treated mathematically. Besides which the physical processes of natural flight of the creatures have become the subject of minute investigation, and have in most cases been satisfactorily explained. The nature of the wind, also, and its influence on flying bodies, have been carefully studied, thus enabling us to understand several peculiarities of the birds' flight hitherto unexplainable, so that once can apply the results thus obtained in perfecting human flight.

The theoretical apparatus needed for the technics of flying has been enriched so much by all these studies within the last few years that the elements of flying apparatus can now be calculated and constructed with sufficient accuracy. By means of this theoretical knowledge one is enabled to form and construct wing and sailing surfaces according as the intended effect renders it desirable.

But with all this, we are not yet capable of constructing and using complete flying machines which answer all requirements. Being desirous of furthering with all speed the solution of the problem of flight, men have repeatedly formed projects in these last few years which represent complete air ships moved by dynamos; but the constructors are not aware of the difficulties which await us as soon as we approach the realizing of any ideas in flying.

From a raised starting point, particularly from the top of a flat hill, one can, after some practice, soar through the air, reaching the earth only after having gone a great distance.

For this purpose I have hitherto employed a sailing apparatus very like the outspread pinions of a soaring bird. It consists of a wooden frame covered with shirting (cotton twill). The frame is taken hold of by the hands, the arms resting between cushions, thus supporting the body. The legs remain free for running and jumping. The steering in the air is brought about by changing the center of gravity. This apparatus I had constructed with supporting surfaces of ten to twenty square meters. The larger sailing surfaces move in an incline of one to eight, so that one is enabled to fly eight times as far as the starting hill is high. The steering is facilitated by the rudder, which is firmly fastened behind in a horizontal and vertical position. The machines weigh, according to their size, from fifteen to twenty-five kilogrammes (thirty-three to fifty-five lbs.) In order to practice flying with these sailing surfaces one first takes short jumps on a somewhat inclined surface till he has accustomed himself to be borne by the air. Finally he is able to sail over inclined surfaces as far as he wishes. The supporting capacity of the air is felt, particularly if there is a

[4 Abbildungen auf denen Lilienthal mit seinem Doppeldecker im Flug zu sehen ist.]

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breeze. A sudden increase in the wind causes a longer stoppage in the air, or one is raised to a still higher point. The charm of such flight is indescribable, and there could not be a healthier motion or more exciting sport in the open air.

The apparatus which I now employ for my flying exercise contains a great many improvements as compared with the first sailing surfaces with which I commenced this kind of experiment five years ago. The first attempts in windy weather taught me that suitable steering surfaces would be needed to enable me to keep my course better against the wind. Repeated changes in the construction led to a kind of apparatus with which one can throw himself without danger from any height, reaching the earth safely after a long distance. The construction of the machine is such that it resembles in all its parts a strut frame, the joints of which are calculated to stand pull and pressure, in order to combine the greatest strength with the last weight.

An important improvement was to arrange the apparatus for folding. All of my recent machines are so arranged that they can be taken through a door two meters high. The unfolding and putting together of the flying implements takes about two minutes. A single grip of the hands is sufficient to attach the apparatus safely to the body, and one gets out of the apparatus just as quickly on landing. In case of a storm flying sail is folded up in half a minute and can be laid anywhere. If one should not care to fold the apparatus, he may await the end of the storm under cover of the wings, which are capable of protecting twenty persons. Even the heaviest rain will not damage the apparatus. The flying apparatus, even if completely drenched, is soon dried by a few sailing flights after the rain stops, as the air passes through the same with great speed. The latest improvements of the flying apparatus which I use for practical experiments refer to gaining of greater stability in windy weather.

My experiments tend particularly in two directions. On the one side I endeavor to

carry my experiments in sailing through the air with immovable wings to this extent: I practice the overcoming of the wind in order to penetrate, if possible, into the secret of continued soaring flight. On the other hand, I try to attain the dynamic flight by means of flapping the wings, which are introduced as a simple addition to my sailing flights. The mechanical contrivances necessary for the latter, which can reach a certain perfection only by gradual development, do not allow yet of my making known any definite results. But I may state that since my sailing flights of last summer, I am on much more intimate terms with the wind.

What has prevented me till now from using winds of any strength for my sailing experiments has been the danger of a violent fall through the air, if I should not succeed in retaining the apparatus in those positions by which one insures a gentle landing. The wildly rushing wind tries to dash about the free floating body, and if the apparatus take up a position, if only for a short time, in which the wind strikes the flying surfaces from above, the flying body shoots downward like an arrow, and can be smashed to pieces before one succeeds in attaining a more favorable position in which the wind exercises a supporting effect. The stronger the wind blows, the easier this danger occurs, as the gusts of wind are so much the more irregular and violent.

As long as the commotion of the air is but slight, one does not require much practice to go quite long distances without danger. But the practice with strong winds is interesting and instructive, because one is at times supported quite by the wind alone. The size of the apparatus, however, unhappily limits us. We may not span the sailing surfaces beyond a certain measure, if we do not wish to make it impossible to manage them in gusty weather. If the surfaces of 14 square meters (about 150 square feet) do not measure more than 7 meters (about 23 feet) from point to point, we can eventually overcome moderate winds of about 7 meters (about 22 miles per hour) velocity, provided one is well practiced. With an apparatus of this size it has happened to me that a sudden increase in the wind has taken me way up out of the usual course of flying, and has sometimes kept me for several seconds at one point of the air. It has happened in such a case that I have been lifted vertically by a gust of wind from the top of the hill, floating for a time above the same at a height of about 5 meters, whence I then continued my flight against the wind.

The means by which I sought to facilitate the management of the machines and to increase their use in wind consisted in the first place in different arrangements for changing the shape of the wings at will. I will, however, pass over the results here obtained, as another principle gave surprisingly favorable results. My experiments in sailing flight have accustomed me to bring about the steering by simply changing the center of gravity.

The smaller the surface extension of the apparatus is, the better control I have over it, and yet if I employ smaller bearing surfaces in stronger winds, the results are not more favorable. The idea therefore occurred to me to apply two smaller surfaces, one above the other, which both have a lifting effect when sailing through the air. Thus the same results must follow which would be gained by a single surface of twice the bearing capacity, but in account of its small dimensions this apparatus obeys much better the changes of the center of gravity.

Before I proceeded to construct these double sailing machines, I made small models

in paper after that system, in order to study the free movements in the air of such flying bodies and then to construct my apparatus on a large scale, depending on the results thus obtained.

I need only recall the extensive and expensive experiments made by Messrs. Riedinger, Von Sigsfeld, and Von Parseval of Augsburg, which showed the difficulty of constructing models that would automatically take up a course of stable flight. I myself doubted formerly very much that an inanimate body sailing quickly forward could be well balanced in the air, and was all the better pleased in succeeding in this with my little double surfaces. Relaying on this experience I constructed first a double apparatus in which each surface contains 9 square meters (about 97 square feet). I thus produced a comparatively large bearing surface of 18 square meters with but 5½ meters (about 18 feet) span. The upper surface is separated from the lower by distance equal to threequarters of the breadth of the lower surface, and it has no disturbing influence whatever, but creates only a vertically acting lifting force. One must consider that with such an apparatus one always cuts the air quickly, so that both surfaces are met by the air current, and therefore both act as lifters.

The whole management of such an apparatus is just the same as that of a single sailing surface. I could, therefore, use at once the skill I had already obtained. I had to change the center of gravity, and particularly the position of the legs, to the left, in order to press down the left wing, which is a little raised. In Fig. 1 the opposite movement to the right is shown. I retain the middle position whenever the apparatus floats horizontally.

The flights undertaken with such double sailing surfaces are distinguished by their great height, as is shown in Fig. 2, which gives a side view of the apparatus.

The landing with this apparatus is brought about in the same way as with the single sailing surfaces by raising the apparatus in front somewhat and by lessening the speed, as shown in Fig. 3.

Fig. 4. shows an exact picture of the construction of the apparatus, as well as of the management of the same.

The energetic effect of the change of the center of gravity and the safe starting of the apparatus obtained by it gave me courage to trust myself to a wind which at times exceeded a velocity of 10 meters (about 24 miles an hour).

This gave the most interesting results of all my practical flying experiments hitherto. Six or seven meters velocity of wind sufflced to enable the sailing surface of 18 square meters to carry me almost horizontally against the wind from the top of my hill without any starting jump. If the wind is stronger, I allow myself to be simply lifted from the point of the hill and to sail slowly toward the wind. The direction of the flight has, with a strong wind, a strong upward tendency. I often reach positions in the air which are much higher than my starting point. At the climax of such a line of flight I sometimes come to a standstill for some time, so that I am enabled while floating to speak with gentlemen who wish to photograph me, regarding the best position for the photographing.*

At such times I feel plainly that I would remain floating if I leaned a little toward one side, described a circle and proceeded with the wind. The wind itself tends to bring this motion about, for my chief occupation in air consists in preventing a turn either to right or

the left, and I know that the hill from which I started lies behind and underneath me, and that I might come into rough contact with it if I attempted circling. My endeavors tend, therefore, to remove myself farther from the hill either by increased wind or by flapping with the wings, so that I can follow the strongly lifting air current in a circle and so that I can have a sufficient space of air under and beside me to succeed in describing with safety a circling flight and to land finally steering against the wind.

As soon as I or any other experimenter succeeds in describing the first circling flight, one may regard this event as one of the most important conquests on the road to perfect flight. From this moment only, one is enabled to make a thorough use of the vis viva of the wind, so that when the wind increases one is able to steer against it, and when it decreases one can fly with it, getting beyond the same. One will fell here a similar effect, as already described by Prof. Lang-

*The photographs were made by Drs. Neuhaus and Fulleborn, who used a camera constructed by Dr. Neuhaus on the Stegemann principle.

ley in his celebrated treatise entitled “The Internal Work of the Wind.” It is no easy step from the theoretical conviction to the practical execution. The dexterity required to allow one's self to be borne by the wind alone, by describing well directed circles, is only understood by those who are well acquainted with the difficulties one encounters with the wind. And yet all that may be acquired by practice. When the time comes that athletic associations emulate each other, such results will not be long in following.

Moreover, experimenters will proceed from simple floating and sailing, which in any case form the foundation for practical flight, by degrees to flying with movable implements. As one is enabled to balance himself for some time in the air, the foundations for more extended dynamic effects are easily and safely attained. The different projects may be easily tried by adding the motor work to the simple sailing flight taken as a basis. In this manner one will soon find out the best methods; for practical experience in the air is far better than figuring on paper.

The only thing which may cause difficulties is the procuring of a suitable place for practicing. Just as the starting from the earth is rather difficult for larger birds, the human body, being still heavier, meets with peculiar difficulties at the first flight upward. The larger birds take a running start against the wind or throw themselves into the air from elevated points, in order to obtain free use of their pinions. As soon, however, as they float in the air, their flight, which was begun under special difficulties, is easily continued. The case is similar in human flight. The principal difficulty is the launching into the air, and that will always necessitate special preparations. A man will also have to take a running start against the wind with his flying apparatus, but on a horizontal surface even that will not be sufficient to free himself from the earth. But on taking a running start from a correspondingly inclined surface, it is easy to begin one's flight, even if there is no wind. According to the example of birds, man will have to start against the wind; but as an inclined surface is necessary for this, he needs a hill having the shape of a flat cone, from the top of which he may take starts against the wind in any direction. Such a place is absolutely necessary, if one wishes to make flying experiments in a convenient way without being dependent on the direction of the wind. For this purpose I have had an artificial hill, fifteen meters high, erected near my house in Gross Lichterfelde, near Berlin, and so have

been enabled to make numerous experiments. The drawings show this hill or part of the same, from the outside.

If the atmosphere is undisturbed, the experimenter sails with uniform speed; as soon, however, as even a slight breeze springs up, the course of the flight becomes irregular. The apparatus inclines now to the right, now to the left.

The person flying ascends from the usual line of flight, and, borne by the wind, suddenly remains floating at a point high in the air; the onlookers hold their breath; all at once cheers are heard, the sailer proceeds and glides amid the joyful exclamations of the multitude in a graceful curve back again to the earth.

Can any sport be more exciting than flying? Strength and adroitness, courage and decision, can nowhere gain such triumphs as in these gigantic bounds into the air, when the gymnast safely steers his soaring machine house high over the heads of spectators.

That the danger here is easily avoided when one practices in a reasonable way, I have sufficiently proved, as I myself have made thousands of experiments within the last five years, and have had no accidents whatever, a few scratches excepted. But all this is only a means to the end; our aim remains-the developing of human flight to as high a standard as possible. For the cuts and copy we are indebted to the Aeronautical Annual for 1896.