THE PROBLEM OF FLYING.*

By OTTO LILIENTHAL.

While theoretically no difficulty of any considerable importance precludes flight, the problem can not be considered solved until the act of flying has been accomplished by man. In its application, however, unforeseen difficulties arise of which the theorist can have no conception.

The first obstacle to be overcome by the practical constructor is that of stability. It is an old adage that "*Wasser hat keine Balken.*"† What then, shall be said of air?

Leaving out of the question propelling mechanisms which require more than ordinary refinements of construction, theory teaches that a properly constructed flying apparatus may be brought to sail in a sufficiently strong wind; while in still air, such a machine may be made to glide downward upon a slightly inclined path. In the practical application of these two methods, however, it is found that while the apparatus is supported by moving air, it is also subjected to the whims of the wind, which often places it in uncomfortable positions, overturns it, or carries it into higher regions and then precipitates it, headforemost, to the ground. Lowering of the center of gravity is of little avail, nor does the most ingenious change of the wings or the steering surfaces alter the case. There is still no trace of the majestic soaring of the bird, for the wind is a treacherous fellow, who follows his own inclinations and laughs at our art. Therefore let us try the second method, the oblique descent in still air.

According to computation the apparatus should descend at a small angle, reaching the ground at a considerable distance, but this experiment is a success only in short flights. Beyond these the apparatus becomes unmanageable, darts vertically up, turns about, comes to a full stop, stands on its head, and descends with uncomfortable rapidity to the ground, the contact with which will probably have demolished the machine, if it do not turn a lucky somersault and land upon its

* Translated abstract of a paper from *Prometheus*, No. 205, 1893, vol. IV, pp. 769–774.

† Water has no rafters.

back. Nor do repeated changes of the center of gravity alter the case beyond making it turn over backward instead of forward, leaving the conditions as unstable as before. Fancy the fate of the man who confides in such an apparatus.

Shall we now give up all hopes of success or shall we try new means to deprive the flying machine of its vicious propensities? This question has been answered in various ways. On the one hand it is thought that it should be possible, by mechanical means, to produce stable flight automatically, and an association of engineers of repute at Augsburg—an excellent proof that investigations of the art of flying have begun to be taken up by willing and self-sacrificing men—has among other things proposed mechanical contrivances for the regulation of soaring.

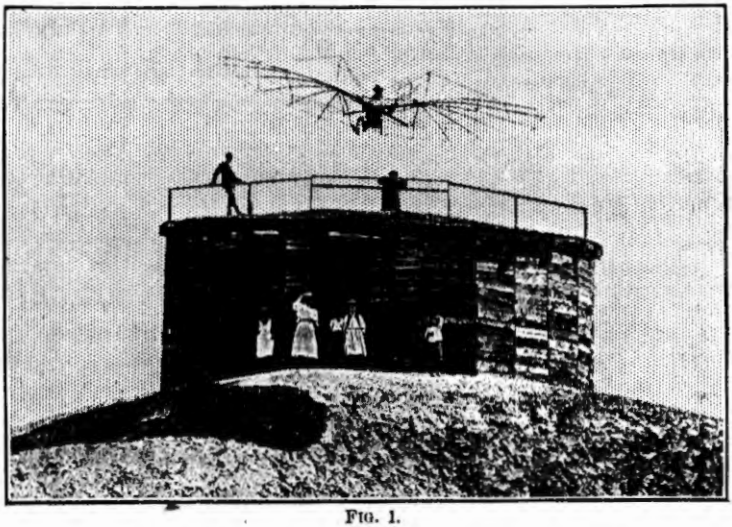

FIG. 1.

The apparatus is meant to descend from a captive balloon. By the application of ingenious methods the sailing surfaces (wings) are forced to retain their inclination. According to the report of Engineer M. Von Siegsfeld on the subject, no system has as yet been discovered that would promise sufficient security to any one sailing at a considerable elevation.

As desirable as it is that these investigations should discover safe automatic devices to give stability to soaring, it remains, on the other hand, doubtful whether the dangers attending such flights could even then be obviated. I am of the opinion that the evolution of the flying machine will be similar to that of the bicycle, which was not made in a day, and that this will not be either. Although in soaring the center of gravity may be placed below the center of pressure of the supporting air, it appears that even in this case, on account of the elasticity of the air itself, permanent stability could only be obtained by a constant and arbitrary correction of the position of the center of gravity. This

is performed by birds incessantly and it is in virtue of a perfect adaptation of the form of their wings to any aerial motion that their flight appears to us so sure, graceful, and beautiful.

In the same way a man can move through the air and have the general ability to guide his apparatus by a constant shifting of the center of gravity. Descent should not be at first tried from great elevations, for such a feat requires practice. In the beginning, the height should be moderate and the wings not too large, or the wind will soon show that it is not to be trifled with. In fact, under some circumstances, one may be swept off toward still higher regions, the descent from which might well be disastrous. It therefore seems best that the wings should not exceed from 8 to 10 square meters (somewhat over 80 to 100 square feet), or that the experiment should be conducted in any wind blowing more than 5 meters per second (nearly 1,000 feet a minute), which represents a gentle breeze. A good run against the wind, however, and a leap from a safe height of 2 or 3 meters may secure a flight of 15 or 20 meters.

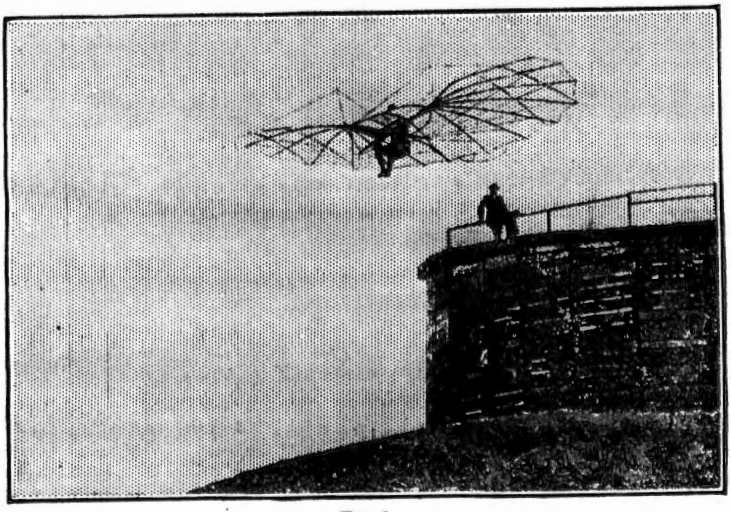

FIG. 2.

Continual practice will enable the experimenter to withstand a stronger breeze, to increase the surface of the wings to 15 square meters (160 square feet), and to start from a greater elevation, especially if there be a moderate slope beneath him with a soft, yielding surface. After becoming sufficiently expert to deviate from a straight line, the experimenter may enjoy the sensation of flying, but it is always a necessary condition that he should face the wind while descending, as the birds do. If then flight is attempted with the wind, it must be more rapid than the wind, or the result will be very apt to be a dangerous somersault at the time of coming to the ground, so that it is, on the whole, most advisable to follow the lessons of the birds, who ascend and descend against the wind.

I have been experimenting in this way for three years, and the constant progress made in the perfection of my machine and the increased security it gives has convinced me of the correctness of the plan. At all events, I think it best to perfect the soaring apparatus before attempting flight with movable wings.

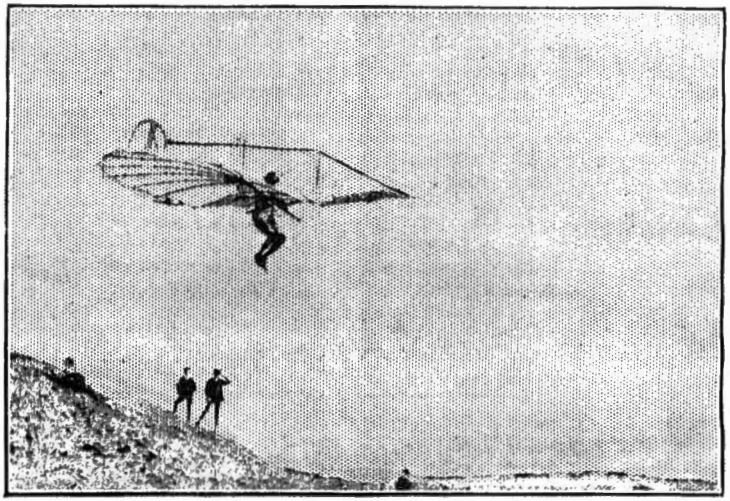

FIG. 3.

After numerous experiments from low elevations, I gradually ventured to increase the height, and for this purpose I erected a tower-like shed, which, while it gave me room to store my apparatus, enabled me to conduct my experiments from the roof. The illustrations, taken from instantaneous photographs, show one of my securely constructed machines for soaring and the various phases of a soaring experiment.

Figure 1 represents the first leap from the roof, the cut showing the front view of the apparatus, which in some respects resembles the spread wings of a bat, and folds up like those for convenience of storage and transportation. The frame is of willow, covered with sheeting; the entire area contains nearly 150 square feet, and the entire apparatus weighs about 45 pounds. The roof of the tower is rather over 30 feet above the surrounding level, and from this elevation, after sufficient practice, one may glide over a distance of over 50 yards at an angle of descent of from 10 to 15 degrees.

Figures 2, 3, 4 show the progess of the experiment. While flying freely in the air the proper angle of descent has to be regulated by shifting the center of gravity. Of course, the wind plays a very important part here, and it is only by long and constant practice that we can learn to make allowance for its irregularities and to steer the apparatus properly. The capriciousness of the wind may exert unequal pressure on the great expanse of wing, and then it may happen that one wing will be elevated higher than the other.

This is shown in fig. 5. In this case the equilibrium may be restored by a change in the center of gravity, which may be effected by extending the legs as far to the left as possible, and thus adding more weight

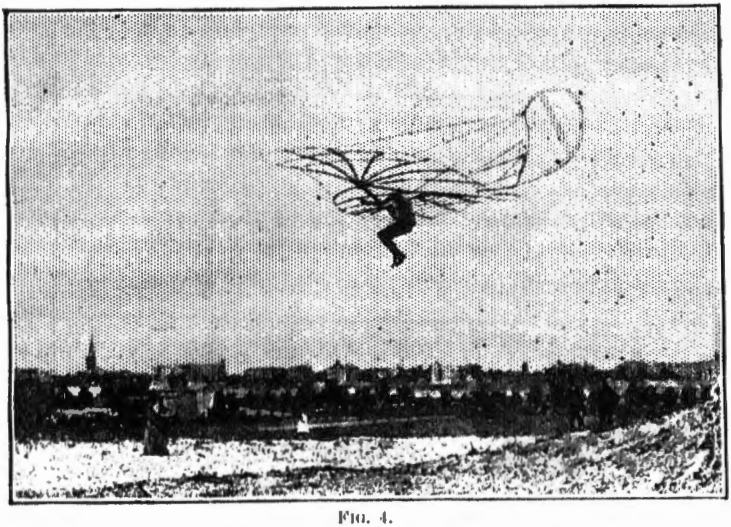

FIG. 4.

to the wing on that side. The two steering planes attached to the rear aid in enabling one to keep the face to the wind.

Figure 6 shows the simple manner of grasping the machine. There are no straps or buckles, and yet the connection is perfect. Each

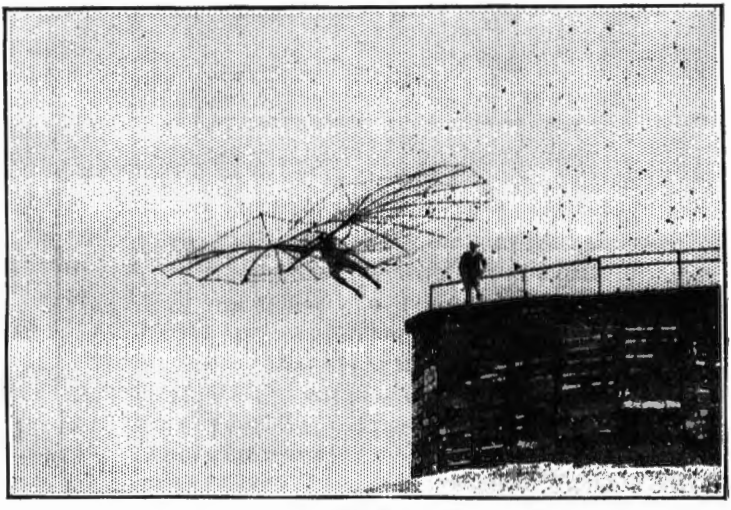

FIG. 5.

arm rests on a cushion attached to the framework, the hands seize a cross-bar, and the remainder of the body hangs free.

My recent experiments have been made from hills having an elevation of about 250 feet and sloping uniformly every way at an angle of 10 to 15°. From the lower ridges I have already sailed a distance of over 250 yards. The great difficulty to be encountered in the endeavor to soar comes in learning to guide the flight, rather than in the difficulty of providing power to move the wings.

Progress in the mechanics of flying received at one time a severe check through the utterances of a high authority in physics. Starting with an erroneous hypothesis and putting too high a value on the amount of work required, he claimed that the maximum of possible flight had already been developed in the largest birds, and, as man represented about four times the heaviest of them, human flight was

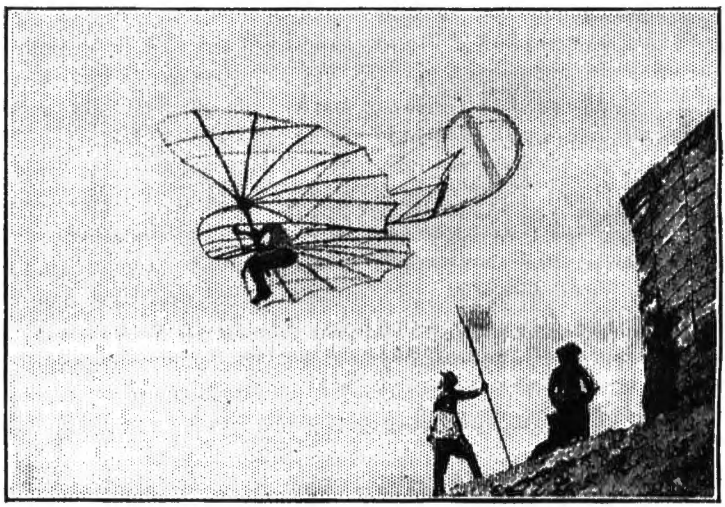

FIG. 6.

to be discarded as an utter impossibility. Now, it must be admitted that the difficulties increase with the size of the flying individual; but flying itself is not the difficulty, for the largest flyers are at the same time the best flyers when they once get going in the air.

The object of this paper is to attempt to dispel old prejudices and to win new adherents for the problem in question. Even considered only as a physical exercise, the sport of flying would create one of the healthiest of all enjoyments and add one of the most effective remedies to the means now adopted for the conquest of those diseases which are incident to our modern culture.