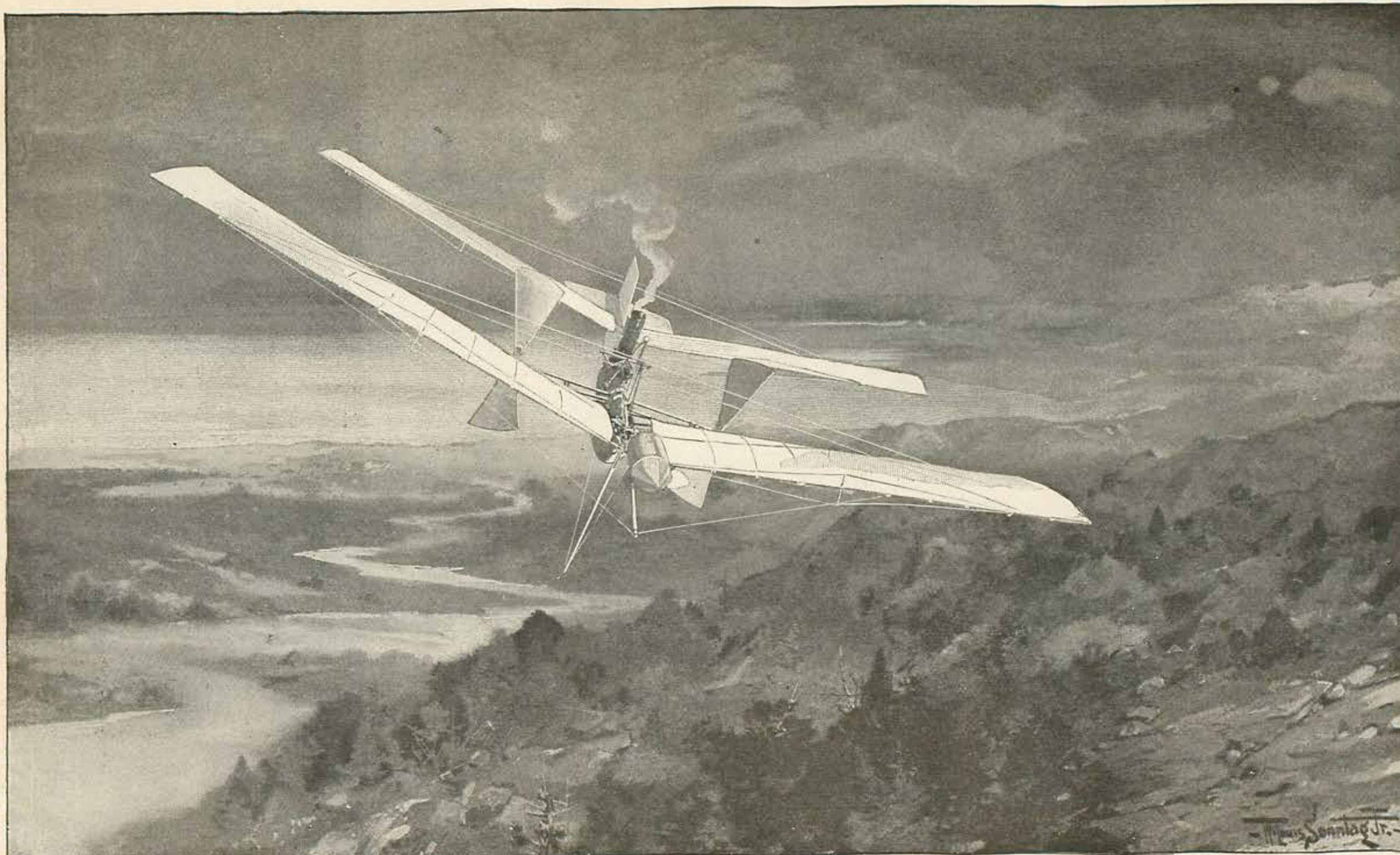


From a] THE AËRODROME IN FLIGHT—SEEN FROM ABOVE. [*Drawing.*

The New Flying-Machine.

By Professor S. P. Langley.

(Secretary of the Smithsonian Institution.)

With illustrations made directly from Professor Langley's machine, and approved by him.

I HAVE been asked to prepare an account of my flying-machine, which has actually flown for considerable distances, and thus, at last, solved the problem of aerial flight. There is in preparation a description of this work for the professional reader, but in view of the great general interest in it, and of the numerous unauthorized statements about it, it has seemed well to write provisionally the informal and popular account which is now given. The work has occupied so much of my life that I have presented what I have to say at present in narrative form.

By "flying-machine" is here meant something much heavier than the air, and entirely different in principle from the balloon, which floats only on account of its lightness, as a ship in water. Nature has made her flying-machine in the bird, which is nearly a thousand times as heavy as the air its bulk displaces, and only those who have tried to rival it know how inimitable her work is, for the "way of a bird in the air" remains as wonderful to us as it was to Solomon, and the sight of the bird has constantly held this wonder before men's eyes and in some men's minds, and kept the flame of hope from utter extinction, in spite of long disappointment. I well remember how, as a child, when lying in a New England pasture, I watched a hawk soaring far up in the blue, and sailing for a long time without any motion of its wings, as though it needed no work to sustain it, but was kept up there by some miracle. How wonderfully easy, too, was its flight! There was not a flutter of its pinions as it swept over the field, in a motion which seemed as effortless as that of its shadow.

After many years and in mature life, I was brought to think of these things again, and to ask myself whether the problem of artificial flight was as hopeless and as absurd as it was then thought to be. Nature had solved it, and why not man? Perhaps it was because he had begun at the wrong end, and attempted to construct machines to fly before knowing the principles on which flight rested. I turned for these principles to my books, and got no help. Sir Isaac Newton had indicated a rule for finding the resistance to advance through the air, which seemed, if correct, to call for enormous mechanical power; and a distinguished French mathematician had given a formula showing how rapidly the power must increase with the velocity of flight, and according to which a swallow, to attain a speed it is now known to reach, must be possessed of the strength of a man.

Remembering the effortless flight of the soaring bird, it seemed that the first thing to do was to discard rules which led to such results, and to commence new experiments; not to build a flying-machine at once, but to find the principles upon which one should be built; to find, for instance, with certainty by direct trial, how much horse-power was needed to sustain a surface of given weight by means of its motion through the air.

Having decided to look for myself at these questions, and at first hand, the apparatus for this preliminary investigation was installed at Alleghany, Pennsylvania, about ten years ago. It consisted of a "whirling table" of unprecedented size, mounted in the open air, and driven round by a steam-engine, so that the end of its revolving arm swept through a circumference of two hundred feet, at all speeds up to seventy miles an hour. At the end of this arm was placed the apparatus to be tested, and, among other things, this included surfaces disposed like wings, which were hung from the end of the arm and dragged through the air, till its resistance supported them as a kite is supported by the wind. One of the first things observed was, that if it took a certain strain to sustain a properly disposed weight while it was stationary in the air, then not only to suspend it but to advance it rapidly at the same time took less strain than in the first case. A plate of brass weighing one pound, for instance, was hung from the end of the arm by a spring, which was drawn out till it registered that pound weight when the arm was still. When the arm was in motion, with the spring pulling the plate after it, it might naturally be supposed that, as it was drawn faster, the pull would be greater, but the contrary was observed, for under these circumstances the spring *contracted*, till it registered less than an ounce. When the speed increased to that of a bird, the brass plate seemed to float on the air; and not only this, but taking into consideration both the strain and the velocity, it was found that absolutely less power was spent to make the plate move fast than slow, a result which seemed very extraordinary, since in all methods of land and water transport a high speed costs much more power than a slow one for the same distance.

These experiments were continued for three years, with the general conclusion that by simply moving any given weight of this form fast enough in a horizontal path, it was possible to sustain it with less than one-twentieth of the power that Newton's rule called for. In particular it was proved that if we could insure horizontal flight without friction, about two hundred pounds of such plates could be moved through the air at the speed of an express train and sustained upon it, with the expenditure of one horse - power — sustained, that is, without any gas to lighten the weight, or by other means of flotation than the air over which it is made to run, as a swift skater runs safely over thin ice, or a skipping stone goes over water without sinking, till its speed is exhausted. This was saying that, so far as power alone was concerned, mechanical flight was theoretically possible with engines we could then build, since I was satisfied that boilers and engines could be constructed to weigh less than twenty pounds to the horse-power, and that one horse-power would, in theory at least, support nearly ten times that if the flight were *horizontal*. Almost everything, it will be noticed, depends on this, for if the flight is downward it will end at the ground, and if upward the machine will be climbing an invisible hill, with the same or a greater effort than every bicyclist experiences with a real one. Speed, then, and this speed expended in a horizontal course, were the first two requisites. This was not saying that a flying-machine could be started from the ground, guided into such flight in any direction, and brought back to earth in safety. There was, then, something more than power needed—that is, skill to use it, and the reader should notice the distinction. Hitherto it had always been supposed that it was wholly the lack of mechanical power to fly which made mechanical flight impossible. The first stage of the investigation had shown how much, or rather how little, power was needed in theory for the horizontal flight of a given weight; and the second stage, which was now to be entered upon, was to show first how to procure this power with as little weight as possible, and, having it, how by its means to acquire this horizontal flight in practice—that is, how to acquire the *art* of flight or how to build a ship that could actually navigate the air.

PROFESSOR S. P. LANGLEY.
From a Painting by Robert Gordon Hardie.

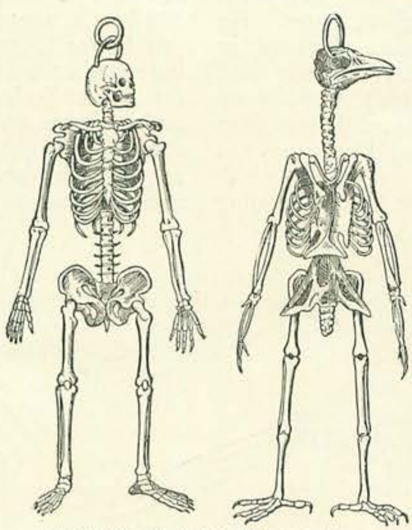
One thing which was made clear by these preliminary experiments, and made clear nearly for the first time, was that if a surface be made to advance rapidly, we secure an essential advantage in our ability to support it. Clearly we want the advance to get from place to place, but it proves also to be the only practicable way of supporting the thing at all, to thus take advantage of the inertia of the air, and this point is so all-important that we will renew an old illustration of it. The idea in a vague sense is as ancient as classical times. Pope says:—

Swift Camilla scours the plain,
Flies o'er the unbending corn, and skims along the main.

Now, is this really so in the sense that a Camilla, by running fast enough, could run over the tops of the corn? *If* she ran fast enough, yes; but the idea may be shown better by the analogous case of a skater who can glide safely over the thinnest ice if the speed is sufficient.

Perhaps we may more fully understand what is meant by looking at a boy's kite. Everyone knows that it is held by a string against the wind which sustains it, and that it falls in a calm. Most of us remember that even in a calm, if we run and draw it along, it will still keep up, for what is required is motion relative to the air, however obtained.

It can be obtained without the cord if the same pull is given by an engine and propellers strong enough to draw it, and light enough to be attached to and sustained by it. The stronger the pull and the quicker the motion, the heavier the kite may be made. It may be, instead of a sheet of paper, a sheet of metal even, like the plate of brass which has already been mentioned as seeming, when in rapid motion, to float upon the air; and, if it will make the principle involved more clear, the reader may think of our aërodrome as a great steel kite made to run fast enough over the air to sustain itself, whether in a calm or in a wind, by means of its propelling machinery, which takes the place of the string.



SKELETONS OF A MAN AND OF A BIRD.

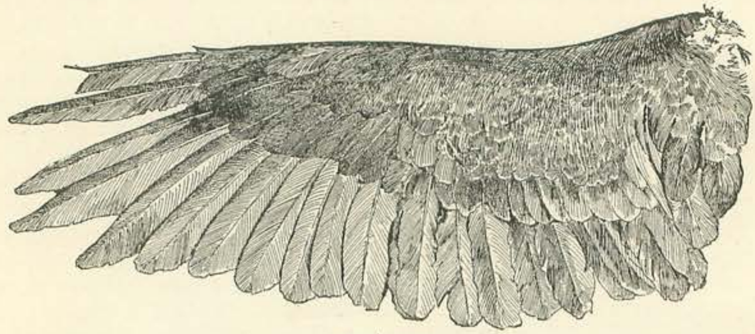
And now, having the theory of the flight before us, let us come to the practice. The first thing will be to provide an engine of unprecedented lightness that is to furnish the power. A few years ago an engine that developed a horse-power weighed nearly as much as the actual horse did. We have got to begin by trying to make an engine which shall weigh, everything complete, boiler and all, not more than twenty pounds to the horse-power, and preferably less than ten; but even if we have done this very hard thing, we may be said to have only fought our way up to an enormous difficulty, for the next question will be how to use the power it gives so as to get a horizontal flight. We must then consider through what means the power is to be applied when we get it, and whether we shall, for instance, have wings or screws. At first it seems as though Nature must know best, and that since her flying models, birds, are exclusively employing wings, this is the thing for us, but perhaps this is not the case. If we had imitated the horse or the ox, and made the machine which draws our trains walk on legs, we should undoubtedly never have done as well as with the locomotive rolling on wheels; or if we had imitated the whale with its fins, we should not have had so good a boat as we now have in the steamship with the paddle-wheels or the screw, both of which are constructions that Nature never employs. This is so important a point that we will look at the way Nature got her models. Here is a human skeleton, and here one of a bird, drawn to the same scale. Apparently Nature made one out of the other, or both out of some common type, and the closer we look, the more curious the likeness appears.

Here is a wing from a soaring bird, here the same wing stripped of its feathers, and here the bones of a human arm, on the same scale. Now, on comparing them we see still more clearly than in the skeleton, that the bird's wing has developed out of something like our own arm. First comes the humerus, or principal bone of the upper arm, which is in the wing also. Next we see that the forearm of the bird repeats the radius and ulna, or two bones of our own forearm, while our wrist and finger-bones are modified in the bird to carry the feathers, but are still there. To make man, then, Nature appears to have taken what material she had in stock, so to speak, and developed it into something that would do. It was all that Nature had to work on, and she has done wonderfully well with such unpromising material ; but anyone can see that our arms would not be the best thing to make flying-machines out of, and that there is no need of our starting there when we can start with something better and develop that. Flapping wings might be made on other principles, and perhaps will be found in future flying-machines, but the most promising thing to try seemed to me to be the screw propeller.

Some twenty years ago, Penaud, a Frenchman, made a toy, consisting of a flat, immovable, sustaining wing surface, a flat tail, and a small propelling screw. He made the wing and tail out of paper or silk, and the propeller out of cork and feathers, and it was driven directly by strands of india-rubber twisted lamp-lighter fashion, and which turned the wheel as they untwisted.

The great difficulty of the task of creating a flying - machine may be partly understood when it is stated that no machine in the whole history of invention, unless it were this toy of Penaud's, had ever, so far as I can learn, flown for even ten seconds, but something that will actually fly must be had to teach the art of "balancing."

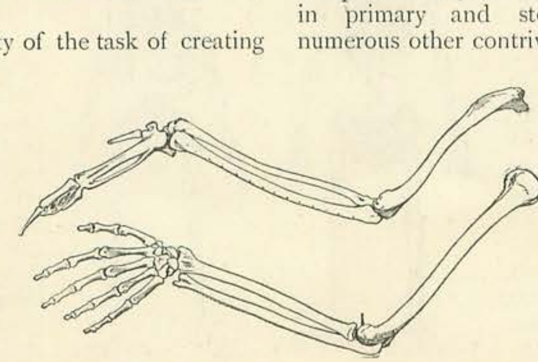
When experiments are made with models moving on a whirling table or running on a railroad track, these are *forced* to move horizontally, and at the same time are held so that they cannot turn over ; but in free flight there will be nothing to secure this, unless the air-ship is so adjusted in all its parts that it tends to move steadily and horizontally, and the acquisition of this adjustment or art of "balancing" in the air is an enormously difficult thing, and which it will be seen later took years to acquire.



A BIRD'S WING.

My first experiments in it, then, were with models like these, but from them I got only a rude idea how to balance the future aërodrome, partly on account of the brevity of their flight, which only lasted a few seconds, partly on account of its irregularity. Although, then, much time and labour were spent by me on these, it was not possible to learn much about the balancing from them.

Thus it appeared that something which could give longer and steadier flights than india-rubber must be used as a motor, even for the preliminary trials, and calculations and experiments were made upon the use of compressed air, carbonic acid gas, electricity in primary and storage batteries, and numerous other contrivances, but all in vain.



SKELETON OF A BIRD'S WING AND OF A MAN'S ARM AND HAND.

The gas-engine promised to be best ultimately, but nothing save steam gave any promise of immediate success in supporting a machine which would teach these conditions of flight by actual trial, for all were too heavy, weight being the great enemy. It was true also that the steam-driven model could not be properly constructed until the principal conditions of flight were learned, nor these be learned till the working model was experimented with, so that it seemed that the inventor was shut up in a sort of vicious circle.

However, it was necessary to begin in some way, or give up at the outset, and the construction began with a machine to be driven by a steam-engine, through the means of propeller wheels, somewhat like the twin screws of a modern steamship, but placed amidships, not at the stern. There were to be rigid and motionless wings, slightly inclined, like the surface of a kite, and a construction was made on this plan which gave, if much disappointment, a good deal of useful experience. It was intended to make a machine that would weigh twenty or twenty-five pounds, constructed of steel tubes. The engines were made with the best advice to be got (I am not an engineer), but while the boiler was a good deal too heavy, it was still too small to get up steam for the engines, which weighed about 4lb., and could have developed a horse-power if there were steam enough. This machine, which was to be moved by two propelling screws, was laboured on for many months, with the result that the weight was constantly increasing beyond the estimate until, before it was done, the whole weighed over 40lb., and yet could only get steam for about a half-horse power, which, after deductions for loss in transmission, would give not more than half that gain in actual thrust. It was clear that, whatever pains it had cost, it must be abandoned.

This aërodrome * could not then have flown, but having learned from it the formidable difficulty of making such a thing light enough, another was constructed which was made in the other extreme, with two engines to be driven by compressed air, the whole weighing but five or six pounds. The power proved insufficient. Then came another with engines to use carbonic acid gas, which failed from a similar cause. Then followed a small one to be run by steam, which gave some promise of success, but when tried indoors it was found to lift only about one-sixth of its own weight. In each of these the construction of the whole was remodelled to get the greatest strength and lightness combined; but though each was an improvement on its predecessor, it seemed to become more and more doubtful whether it could ever be made sufficiently light, and whether the desired end could be reached at all.

The chief obstacle proved to be not with the engines, which were made surprisingly light after sufficient experiment. The great difficulty was to make a boiler of almost no weight which would give steam enough, and this was a most wearying one. There must be also a certain amount of wing surface, and large wings weighed prohibitively; there must be a frame to hold all together, and the frame, if made strong enough, must yet weigh so little that it seemed impossible to make it. These were the difficulties that I still found myself in after two years of experiment, and it seemed at this stage again as if it must, after all, be given up as a hopeless task, for somehow the thing had to be built stronger and lighter yet. Now, in all ordinary construction, as in building a steamboat or a house, engineers have what they call a factor of safety. An iron column will be, for instance, made strong enough to hold five or ten times the weight that is ever going to be put upon it, but if we try anything of the kind here, the construction will be too heavy to fly. Everything in the work has got to be so light as to be on the edge of breaking down and disaster, and when the breakdown comes, all we can do is to find what is the weakest part and make that part stronger, and in this way work went on, week by week and month by month, constantly altering the form of construction so as to strengthen the weakest parts, until, to abridge a story which extended over years, it was finally brought nearly to the shape it is now, where the completed mechanism, furnishing over a horse-power, weighs collectively something less than seven pounds. This does not include water, the amount of which depends on how long we are to run; but the whole thing, as now constructed—boiler, fire-grate, and all that is required to turn out an actual horse-power and more—weighs something less than the one-hundredth part of what the horse himself does. I am here anticipating; but after these first three years something not greatly inferior to this was already reached, and so long ago as that, there had accordingly been secured mechanical power to fly, if that were all—but it is not all.

After that came years more of delay arising from other causes, and I can hardly repeat the long story of subsequent disappointment, which commenced with the first attempts at actual flight.

Mechanical power to fly was, as I say, obtained three years ago; the machine could lift itself if it ran along a railroad track, and it might seem as though, when it could lift itself, the problem was solved. I knew that it was far from solved, but felt that the point

* Aërodrome, from words signifying air-runner, the running over the air being the essence of its plan.

was reached where an attempt at actual free flight should be made, though the anticipated difficulties of this were of quite another order to those experienced in shop construction. It is enough to look up at the gulls or buzzards, soaring overhead, and to watch the incessant rocking and balancing which accompanies their gliding motion, to apprehend that they find something more than mere strength of wing necessary, and that the machine would have need of something more than mechanical power, though what this something was, was not clear. It looked as though it might need a power like instinctive adaptation to the varying needs of each moment, something that even an intelligent steersman on board could hardly supply; but to find what this was, a trial had to be made. The first difficulty seemed to be to make the initial flight in such conditions that the machine would not wreck itself at the outset in its descent, and the first question was where to attempt to make the flight.

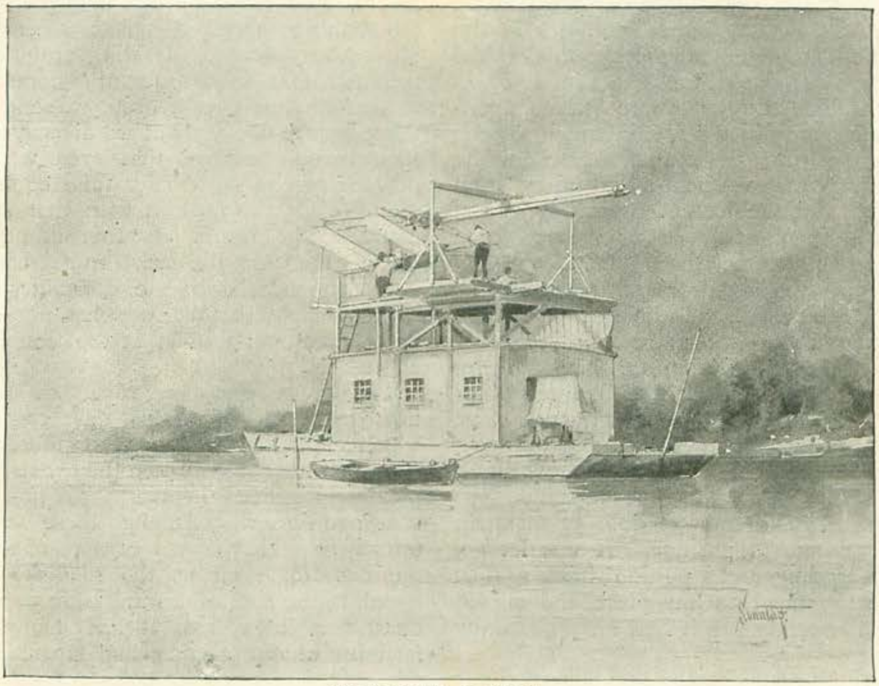
It became clear without much thought that, since the machine was at first unprovided with any means to save it from breakage on striking against the ground, it would be well, in the initial stage of the experiment, not to have it light on the ground at all, but on the water. As it was probable that, while skill in launching was being gained, and until after practice had made perfect, failures would occur, and as it was not desired to make any public exhibition of these, a great many places were examined along the shores of the Potomac, and on its high bluffs, which were condemned partly for their publicity, but partly for another reason. In the course of my experiments I had found out, among the infinite things pertaining to this problem, that the machine must begin to fly in the face of the wind, and just in the opposite way to a ship, which begins its voyage with the wind behind it. If the reader has ever noticed a soaring bird get upon the wing, he will see that it does so with the breeze against it, and thus whenever the aërodrome is cast into the air, it must face a wind which may happen to blow from the north, south, east, or west, and we had better not make the launching station a place like the bank of a river, where it can only go one way. It was necessary, then, to send it from something which could be turned in any direction, and taking this need in connection with the desirability that at first the air-ship should light in the water, there came at last the idea (which seems obvious enough when it is stated) of getting some kind of a barge or boat, and building a small structure upon it, which could house the aërodrome when not in use, and from whose flat roof it could be launched in any direction. Means for this were limited, but a little "scow" was procured, and on it was built a primitive sort of a house one story high, and on the house a platform about 10ft. higher, so that the top of the platform was about 20ft. from the water, and this was to be the place of the launch. This boat it was found necessary to take down the river as far as thirty miles from Washington, where I then was (since no suitable place could be found nearer), to an island having a stretch of quiet water between it and the main shore, and here the first experiments in attempted flight developed difficulties of a new kind, difficulties which were partly anticipated, but which nobody would probably have conjectured would be of their actually formidable character, which was such as for a long time to prevent any trial being made at all. They arose partly out of the fact that even such a flying-machine as a soaring bird has to get up an artificial speed before it is on the wing. Some soaring birds do this by an initial run upon the ground, and even under the most urgent pressure cannot fly without it.

Take the following graphic description of the commencement of an eagle's flight (the writer was in Egypt, and the "sandy soil" was that of the banks of the Nile):—

"An approach to within eighty yards aroused the king of birds from his apathy. He partly opens his enormous wings, but stirs not yet from his station. On gaining a few feet more he begins to *walk* away, with half-expanded but motionless wings. Now for the chance, fire! A charge of number three from eleven bore rattles audibly but ineffectively upon his densely feathered body; his walk increases to a run, he gathers speed with his slowly waving wings, and eventually leaves the ground. Rising at a gradual inclination, he mounts aloft and sails majestically away to his place of refuge in the Libyan range, distant at least five miles from where he rose. Some fragments of feathers denoted the spot where the shot had struck him. The marks of his claws were traceable in the sandy soil, as, at first with firm and decided digs, he forced his way; but as he lightened his body and increased his speed with the aid of his wings, the imprints of his talons gradually merged into long scratches. The measured distance from the point where these vanished, to the place where he had stood, proved that with all the stimulus that the shot must have given to his exertions, he had been compelled to run full twenty yards before he could raise himself from the earth."

We have not all had a chance to see this striking illustration of the necessity of getting up a preliminary speed before soaring, but many of us have disturbed wild ducks on the water and noticed them run along it, flapping their wings for some distance to get velocity before they can fly; and the necessity of the initial velocity is at least as great with our flying-machine as it is with a bird.

To get up this preliminary speed, many plans were proposed, one of which was to put the aërodrome on the deck of a steamboat and go faster and faster, until the head wind lifted it off the deck. This sounds reasonable, but is absolutely impracticable, for when the aërodrome is set up anywhere in the open air, we find that the very slightest wind will turn it over, unless it is firmly held.



PREPARING FOR A LAUNCH.
From a Photograph by Professor Graham Bell.

The whole must be in motion, but in motion from something to which it is held till that critical instant when it is set free as it springs into the air.

The house-boat was fitted with an apparatus for launching the aërodrome with a certain initial velocity, and was (in 1893) taken down the river and moored in the stretch of quiet water I have mentioned, the general features of the place being indicated on the map (see page 717), and it was here that the first trials at launching were made under the difficulties to which I have alluded.

Perhaps the reader will take patience to hear an abstract of a part of the diary of these trials, which commenced with a small aërodrome which had finally been built to weigh only about 10lb., which had an engine of not quite one-half horse-power, and which could lift much more than was theoretically necessary to enable it to fly. The exact construction of this early aërodrome is unimportant, as it was replaced later by an improved one, of which a drawing will presently be given; but it was the first outcome of the series of experiments which had occupied three years, though the disposition of its supporting surfaces, which should cause it to be properly balanced in the air, and neither fly up nor down, had yet to be ascertained by trial.

What must still precede this trial was the provision of the apparatus for launching it into the air. It is a difficult thing to launch a ship, although gravity keeps it down upon the ways, but the problem here is that of launching a kind of ship which is as ready to go up into the air like a balloon as to go off sideways, and readier to do either than to go straight forward, as it is wanted to do; for though there is no gas in the flying-machine, its great extent of wing-surface renders it something like an albatross on a ship's deck—the most unmanageable and helpless of creatures until it is in its proper element.

If there were an absolute calm, which never really happens, it would still be impracticable to launch it as a ship is launched, because the wind made by running it along would get under the wings and turn it over. But there is always more or less wind, and even the gentlest breeze was afterward found to make the air-ship unmanageable unless it was absolutely clamped down to whatever served to launch it, and when it was thus firmly clamped, as it must be at several distinct points, it was necessary that it should be released simultaneously at all these at the one critical instant that it was leaping into the air. This is another difficult condition, but that it is an indispensable one may be inferred from what has been said. In the first form of launching-piece this initial velocity was sought to be attained by a spring, which threw forward the supporting frame on which the aërodrome rested; but at this time the extreme susceptibility of the whole construction to injury from the wind, and the need of protecting it from even the gentlest breeze, had not been appreciated by experience. On November 18th, 1893, the aërodrome had been taken down the river, and the whole day was spent in waiting for a calm, as the machine could not be held in position for launching for two seconds in the lightest breeze. The party returned to Washington and came down again on the twentieth, and although it seemed that there was scarcely any movement in the air, what little remained was enough to make it impossible to maintain the aërodrome in position. It was let go, notwithstanding, and a portion struck against the edge of the launching-piece, and all fell into the water before it had an opportunity to fly.

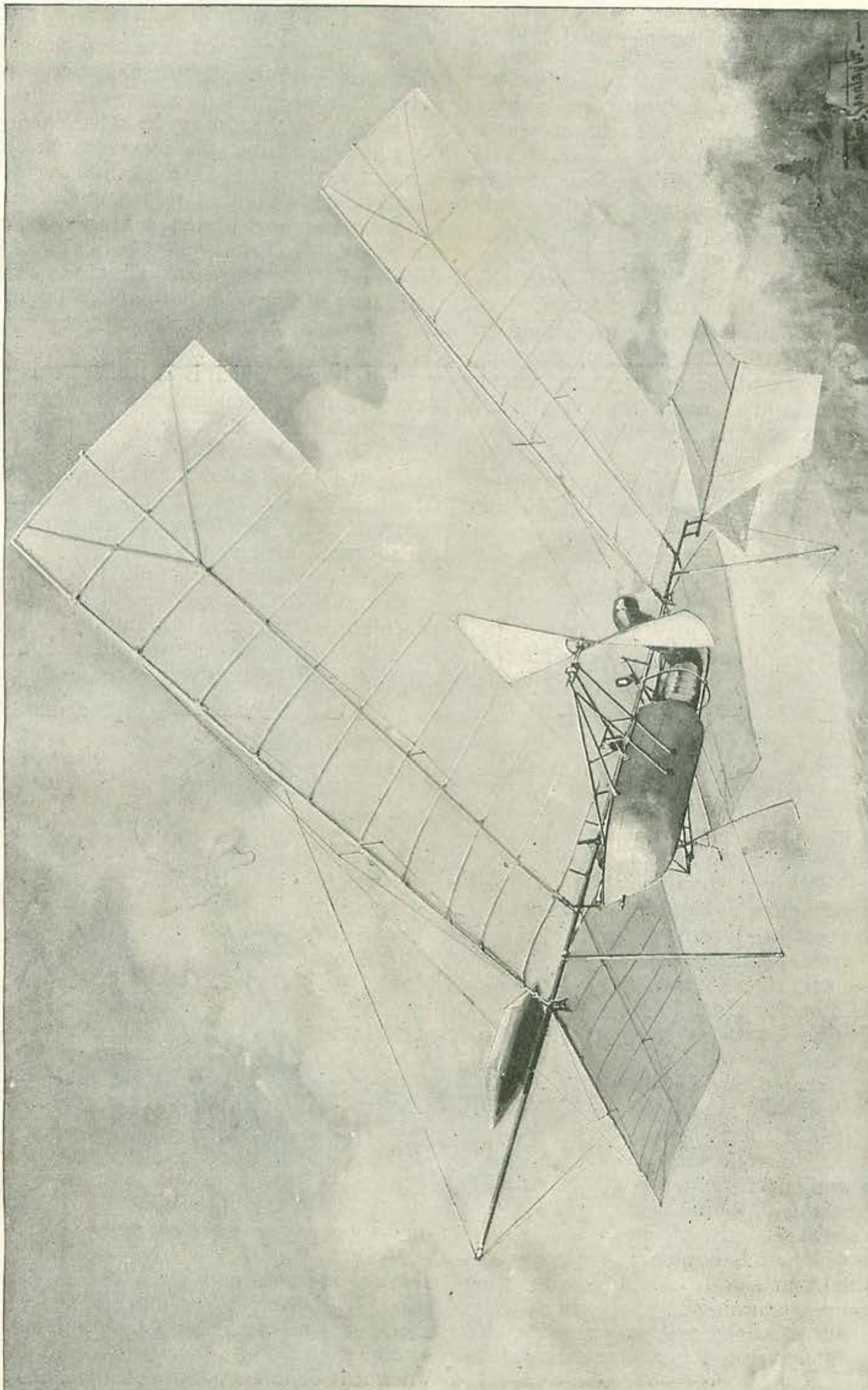
On the twenty-fourth, another trip was made, and another day spent ineffectively on account of the wind. On the twenty-seventh there was a similar experience, and here four days and four (round-trip) journeys of sixty miles each had been spent without a single result. This may seem to be a trial of patience, but it was repeated in December, when five fruitless trips were made, and thus nine such trips were made in these two months, and but *once was* the aërodrome even attempted to be launched, and this attempt was attended with disaster. The principal cause lay, as I have said, in the unrecognised amount of difficulty introduced even by the very smallest wind, as a breeze of three or four miles an hour, hardly perceptible to the face, was enough to keep the air-ship from resting in place for the critical seconds preceding the launching.

If we remember that this is all irrespective of the fitness of the launching-piece itself, which at first did not get even a chance for trial, some of the difficulties may be better understood, and there were many others.

During most of the year of 1894 there was the same record of defeat. Five more trial trips were made in the spring and summer, during which various forms of launching apparatus were tried with varied forms of disaster. Then it was sought to hold the aërodrome out over the water and let it drop from the greatest attainable height, with the hope that it might acquire the requisite speed of advance before the water was reached. It will hardly be anticipated that it was found impracticable at first to simply let it drop, without something going wrong; but so it was, and it soon became evident that even were this not the case, a far greater time of fall was requisite for this method than that at command. The result was that in all these eleven months the aërodrome had not been launched, owing to difficulties which seem so slight that one who has not experienced them may wonder at the trouble they caused.

Finally, in October, 1894, an entirely new launching apparatus was completed, which embodied the dozen or more requisites the need for which had been independently proved in this long process of trial and error. Among these was the primary one that it was capable of sending the aërodrome off at the requisite initial speed, in the face of a wind from whichever quarter it blew, and it had many more facilities which practice had proved indispensable.

This new launching-piece did its work in this respect effectively, and subsequent disaster was, at any rate, not due to it. But now a new series of failures took place, which could not be attributed to any defect of the launching apparatus, but to a cause which was at first obscure, for sometimes the aërodrome, when successfully launched, would dash down forward and down into



From a] THE AËRODROME IN FLIGHT—SEEN FROM BELOW. [*Drawing.*

the water, and sometimes (under apparently identically like conditions) would sweep almost vertically upward in the air and fall back, thus behaving in entirely opposite ways, although the circumstances of flight seemed to be the same. The cause of this class of failure was finally found in the fact that as soon as the whole was upborne by the air, the wings yielded under the pressure which supported them, and were momentarily distorted from the form designed and which they appeared to possess. "Momentarily," but enough to cause the wind to catch the top, directing the flight downward, or under them, directing it upward, and to wreck the experiment. When the cause of the difficulty was found, the cure was not easy, for it was necessary to make these great sustaining surfaces rigid so that they could not bend, and to do this without making them heavy, since weight was still the enemy; and nearly a year passed in these experiments.

Has the reader enough of this tale of disaster? If so, he may be spared the account of what went on in the same way. Launch after launch was successively made. The wings were finally, and after infinite patience and labour, made at once light enough and strong enough to do the work, and now in the long struggle the way had been fought up to the face of the final difficulty, in which nearly a year more passed, for the all-important difficulty of balancing the aërodrome was now reached, where it could be discriminated from other preliminary ones, which have been alluded to, and which at first obscured it. If the reader will look at the hawk or any soaring bird, he will see that as it sails through the air without flapping the wing, there are hardly two consecutive seconds of its flight in which it is not swaying a little from side to side, lifting one wing or the other, or turning in a way that suggests an acrobat on a tight-rope, only that the bird uses its widely outstretched wings in place of the pole.

There is something, then, which is difficult even for the bird, in this act of balancing. In fact, he is sailing so close to the wind in order to fly at all, that if he dips his head but the least he will catch the wind on the top of his wing and fall, as I have seen gulls do, when they have literally tumbled toward the water before they could recover themselves.

Beside this, there must be some provision for guarding against the incessant, irregular currents of the wind, for the wind as a whole —and this is a point of prime importance— is not a thing moving along all-of-a-piece, like water in the Gulf Stream. Far from it. The wind, when we come to study it, as we have to do here, is found to be made of innumerable currents and counter-currents which exist altogether and simultaneously in the gentlest breeze, which is in reality going fifty ways at once, although, as a whole, it may come from the east or the west; and if we could see it, it would be something like seeing the rapids below Niagara, where there is an infinite variety of motion in the parts, although there is a common movement of the stream as a whole.

All this has to be provided for in our mechanical bird, which has neither intelligence nor instinct, and without it, although there be all the power of the engines requisite, all the rigidity of wing, all the requisite initial

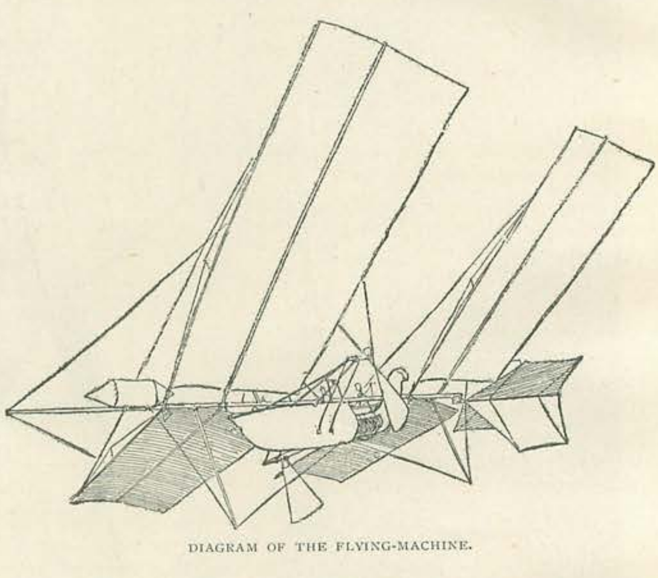


DIAGRAM OF THE FLYING-MACHINE.

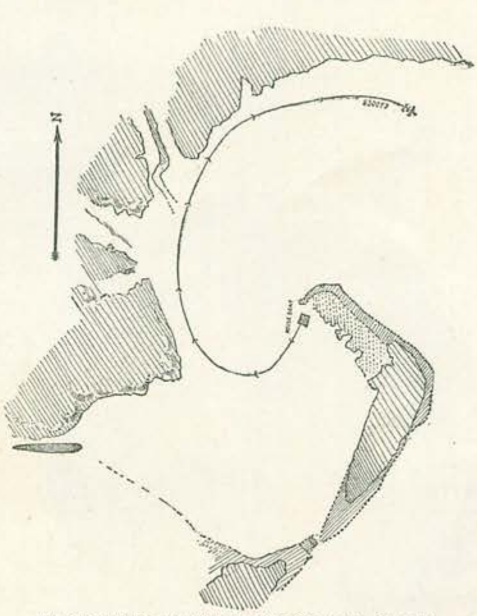
velocity, it still cannot fly. This is what is meant by balancing, or the disposal of the parts, so that the air-ship will have a position of equilibrium into which it tends to fall when it is disturbed, and which will enable it to move of its own volition, as it were, in a horizontal course.

Now the reader may be prepared to look at the apparatus which finally has flown.

In the completed form we see two pairs of wings, each slightly curved, each attached to a long steel rod which supports them both, and from which depends the body of the machine, in which are the boilers, the engines, the machinery, and the propeller wheels, these latter being not in the position of those of an ocean steamer, but more nearly amidships. They are made sometimes of wood, sometimes of steel and canvas, and are between 3ft. and 4ft. in diameter.

The hull itself is formed of steel tubing; the front portion is closed by a sheathing of metal which hides from view the fire-grate and apparatus for heating, but allows us to see a little of the coils of the boiler and all of the relatively large smoke-stack in which it ends. The conical vessel in front is an empty float, whose use is to keep the whole from sinking if it should fall in the water.

This boiler supplies steam for an engine of between one and one and a half horse-power, and, with its fire-grate, weighs a little over 5lb. This weight is exclusive of that of the engine, which weighs, with all its moving parts, but 26oz. Its duty is to drive the propeller wheels, which it does at rates varying from 800 to 1,200, or even more, turns a minute, the highest number being reached when the whole is speeding freely ahead.


COURSE TAKEN BY THE FLYING-MACHINE ON MAY 6TH, 1896.

The rudder, it will be noticed, is of a shape very unlike that of a ship, for it is adapted both for vertical and horizontal steering. It is impossible within the limits of such an article as this, however, to give an intelligible account of the manner in which it performs its automatic function. Sufficient it is to say that it does perform it.

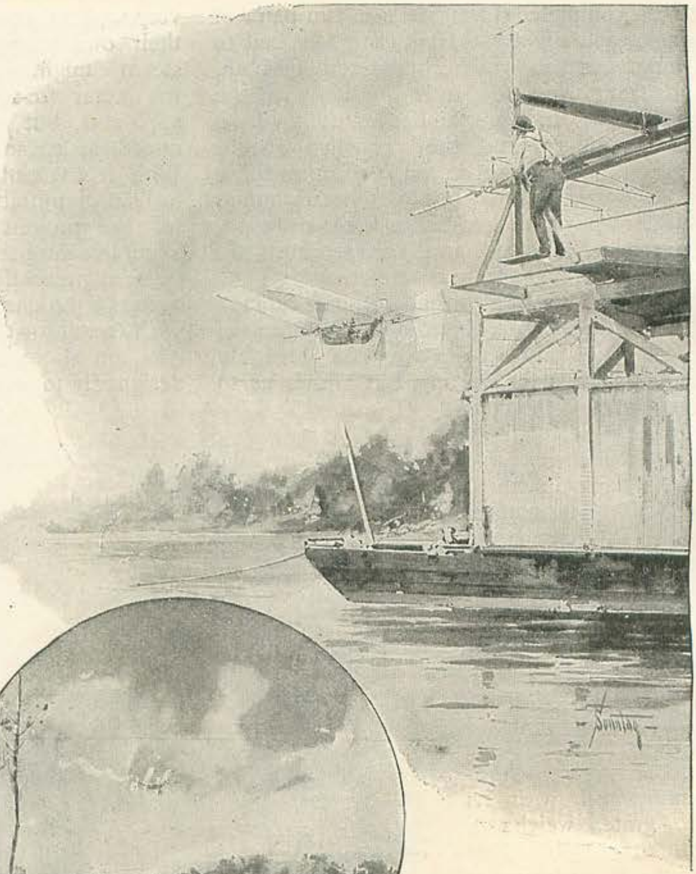
The width of the wings from tip to tip is between 12ft. and 13ft., and the length of the whole about 16ft. The weight is nearly 30lb., of which about one-fourth is contained in the machinery. The engine and boilers are constructed with an almost single eye to economy of weight, not of force, and are very wasteful of steam, of which they spend their own weight in five minutes. This steam might all be recondensed and the water re-used by proper condensing apparatus, but this cannot be easily introduced in so small a scale of construction. With it the time of flight might be hours instead of minutes, but without it the flight (of the present aërodrome) is limited to about five minutes, though in that time, as will be seen presently, it can go some miles; but owing to the danger of its leaving the surface of the water for that of the land, and wrecking itself on shore, the time of flight is limited designedly to less than two minutes.

I have spared the reader an account of numberless delays, from continuous accidents and from failures in attempted flights, which prevented a single entirely satisfactory one during nearly three years after a machine with power to fly had been attained. It is true that the aërodrome maintained itself in the air at many times, but some disaster has so often intervened to prevent a complete flight that the most persistent hope must at some time have yielded. On the 6th of May of last year I had journeyed, perhaps for the twentieth time, to the distant river station, and recommenced the weary routine of another launch with very moderate expectation indeed, and when on that, to me, memorable afternoon the signal was given and the aërodrome sprang into the air,* I watched it from the shore, with hardly a hope that the long series of accidents had come to a close. And yet it had, and for the first time the aërodrome swept continuously through the air like a living thing, and as second after second passed on the face of the stop-watch, until a minute had gone by, and it still flew on, and as I heard

* The illustration, from an instantaneous photograph by Mr. Bell, shows the machine after Mr. Reed, who was in charge of the launch (and to whom a great deal of the construction of the aërodrome is due), has released it, and when it is in the first instant of its aërial journey.

the cheering of the few spectators, I felt that something had been accomplished at last, for never in any part of the world, or in any period, had any machine of man's construction sustained itself in the air before for even half of this brief time. Still the aërodrome went on in a rising course until, at the end of a minute and a half (for which time only it was provided with fuel and water), it had accomplished a little over half a mile, and now it settled rather than fell into the river with a gentle descent. It was immediately taken out and flown again with equal success, nor was there anything to indicate that it might not have flown indefinitely except for the limit put upon it.

I was accompanied by my friend, Mr. Alexander Graham Bell, who not only witnessed the flight, but took the instantaneous photographs of it which are here given.



TWO VIEWS OF FLIGHTS TAKEN MAY 6TH, 1896—FROM INSTANTANEOUS PHOTOGRAPHS.

He spoke of it in a communication to the Institute of France in the following terms :—

Through the courtesy of Mr. S. P. Langley, Secretary of the Smithsonian Institution, I have had on various occasions the privilege of witnessing his experiments with aërodromes, and especially the remarkable success attained by him in experiments made on the Potomac River, on Wednesday, May 6th, which led me to urge him to make public some of these results.

I had the pleasure of witnessing the successful flight of some of these aërodromes more than a year ago, but Professor Langley's reluctance to make the results public at that time prevented me from asking him, as I have done since, to let me give an account of what I saw.

On the date named, two ascensions were made by the aërodrome, or so-called "flying-machine," which I will not describe here further than to say that it appeared to me to be built almost entirely of metal, and driven by a steam-engine which I have understood was carrying fuel and a water-supply for a brief period, and which was of extraordinary lightness.

The absolute weight of the aërodrome, including that of the engine and all appurtenances, was, as I was told, about 25lb., and the distance, from tip to tip, of the supporting surfaces was, as I observed, about 12ft. or 14ft.

The method of propulsion was by aërial screw propellers, and there was no gas or other aid for lifting it in the air except its own internal energy.

On the occasion referred to, the aërodrome, at a given signal, started from a platform about 20ft. above the water, and rose at first directly in the face of the wind, moving at all times with remarkable steadiness, and subsequently swinging around in large curves of, perhaps, 100yds. in diameter, and continually ascending until its steam was exhausted, when, at a lapse of about a minute and a half, and at a height which I judged to be between 80ft. and 100ft. in the air, the wheels ceased turning, and the machine, deprived of the aid of its propellers, to my surprise did not fall, but settled down so softly and gently that it touched the water without the least shock, and was in fact immediately ready for another trial.

In the second trial, which followed directly, it repeated in nearly every respect the actions of the first, except that the direction of its course was different. It ascended again in the face of the wind, afterwards moving steadily and continually in large curves, accompanied with a rising motion and a lateral advance. Its motion was, in fact, so steady that I think a glass of water on its surface would have remained unspilled. When the steam gave out again, it repeated for a second time the experience of the first trial when the steam had ceased, and settled gently and easily down. What height it reached at this trial I cannot say, as I was not so favourably placed as in the first; but I had occasion to notice that this time its course took it over a wooded promontory, and I was relieved of some apprehension in seeing that it was already so high as to pass the tree-tops by 20ft. or 30ft. It reached the water one minute and thirty-one seconds from the time it started, at a measured distance of over 900ft. from the point at which it rose.

This, however, was by no means the length of its flight. I estimated from the diameter of the curve described, from the number of turns of the propellers as given by the automatic counter, after due allowance for slip and from other measures, that the actual length of flight on each occasion was slightly over 3,000ft. It is at least safe to say that each exceeded half an English mile.

From the time and distance it will be noticed that the velocity was between twenty and twenty-five miles an hour, in a course which was constantly taking it "up hill." I may add that on a previous occasion I have seen a far higher velocity attained by the same aërodrome when its course was horizontal.

I have no desire to enter into detail further than I have done, but I cannot but add that it seems to me that no one who was present on this interesting occasion could have failed to recognise that the practicability of mechanical flight had been demonstrated.

ALEXANDER GRAHAM BELL.

On November 28th I witnessed, with another aërodrome of somewhat similar construction, a rather longer flight, in which it traversed about three-quarters of a mile, and descended with equal safety. In this the speed was greater, or about thirty miles an hour. The course of this date is indicated by the dotted line on the accompanying map. We may live to see air-ships a common sight, but habit has not dulled the edge of wonder, and I wish that the reader could have witnessed the actual spectacle. "It looked like a miracle," said one who saw it, and the photograph, though taken from the original, conveys but imperfectly the impression given by the flight itself.

And now, it may be asked, what has been done? This has been done: a "flying-machine," so long a type for ridicule, has really flown; it has demonstrated its practicability in the only satisfactory way—by actually flying, and by doing this again and again, under conditions which leave no doubt.

There is no room here to enter on the consideration of the construction of larger machines, or to offer the reasons for believing that they may be built to remain for days in the air or to travel at speeds higher than any with which we are familiar; neither is there room to enter on a consideration of their commercial value, or of those applications which will probably first come in the arts of war rather than those of peace; but we may at least see that these may be such as to change the whole conditions of warfare, when each of two opposing hosts will have its every movement known to the other, when no lines of fortification will keep out the foe, and when the difficulties of defending a country against an attacking enemy in the air will be such that we may hope that this will hasten rather than retard the coming of the day when war shall cease.

I have thus far had only a purely scientific interest in the result of these labours. Perhaps if it could have been foreseen at the outset how much labour there was to be, how much of life would be given to it, and how much care, I might have hesitated to enter upon it at all. And now reward must be looked for, if reward there be, in the knowledge that I have done the best I could in a difficult task, with results which it may be hoped will be useful to others. I have brought to a close the portion of the work which seemed to be specially mine—the demonstration of the practicability of mechanical flight; and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others. The world, indeed, will be supine if it does not realize that a new possibility has come to it, and that the great universal highway overhead is now soon to be opened.