Otto Lilienthal.
A Memorial address delivered before the
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The irreparable loss which our Society has sustained in the death of Otto Lilienthal is still fresh in our memories. We all remember distinctly the untiring character of him who united the definiteness of aim which characterizes manhood with all the ardor and enthusiasm of youth.
For a long time, more than ten years in fact, Lilienthal was a member of our Society, and only a few of our oldest members can remember the whole of the energy which he devoted to our work. This is why I, who introduced Lilienthal into the Society, will endeavor to show what bis membership really meant; all the more so, as it was I especially who was fortunate enough during the many years of mutual intercourse to really know the depths of this noble character and to learn to appreciate it. During this long period I had the good fortune to be initiated into all the phases of his studies of the problem of manflight.
Otto Lilienthal was born May 23rd, 1848, at Anclam in Pomerania. Up to his sixteenth year he went to the Latin High School of bis native city; in 1864 he entered the Potsdam Technical School; after graduation from this institution in 1866 he began the study of civil engineering by a one year's practical course in Schwartzkopf's machine shops. From 1867 to 1870 he was a student at the Berlin Technical Academy, and he had just been graduated from that academy when, in the summer of 1870, the beginning of the Franco-Prussian war called him into the service.
He served as volunteer in the Fusileer Infantry Regiment of the Guards, and was with that regiment at the siege of Paris. After the campaign was over he took a place as civil engineer in Weber's machine shops at Berlin, and was afterwards, from 1872 to 1880, engaged in the large machine shops of C. Hoppe, of Berlin.
In 1880 he started a machine factory of his own, and succeeded, in the course of time, in bringing it to a flourishing condition by his energy and inventive powers. The products of his machine shops were of great variety. One of his inventions was the construction of light steam motors with serpentine pipes. He also made a specialty of marine signals. His achievements in these procured for him the silver State medal. The fog-horn which could be heard during the time of the Berlin trade exhibition near the Imperial ship was constructed and exhibited by him.
From his earliest youth he had been much interested in the subject of manflight, and as early as 1861, being only thirteen years of age, he began to make practical flying experiments, together with his younger brother Gustavus. The first wings made by the two brothers consisted of light flaps which were fastened to the arms; with these they attempted running downhill. The experiments were mostly made at night by moonlight, the young flying artists being naturally afraid of the teasing of their school-fellows.
The experiments which had been started in Anclam were continued in Potsdam. The two brothers constructed wings which were fastened to the back, and which moved up and down by throwing out the legs as in swimming. In 1867 and 1868 while in college, Lilienthal constructed a more complicated apparatus. In these experiments also his brother Gustavus took an active part.
The experiments interrupted in consequence of the campaign were taken up again as early as the autumn of 1871. Lilienthal had seen that the negative results of previous flying experiments could be traced to the fact that it had been the custom to attempt the solution of the problem of birds' flight trusting only to incomplete and even sometimes erroneous observations; or else to undertake the task of deriving the laws of the mechanics of flight purely theoretically without resorting to any observations at all. Both methods would naturally lead to erroneous results. Lilienthal concluded to investigate the whole subject by means of exact experiment, examining scrupulously all the phenomena to be seen in the flight of birds. He began by measuring- by means of a long series of

systematic measurements – the amount of the resistance of the air which the bird's wing has to overcome when in motion.
These experiments and measurements were for a long period made only by Otto Lilienthal, with the help of his brother. They showed the important and new result, that the curved wings, which nature, as we know, provides exclusively for her subjects, have a much more effective form than the flat surface hitherto so often constructed by men.
Besides this, Lilienthal was the first to point out the phenomenon which he thought was the probable explanation of the action of birds in sailing flight; that is, the existence of aircurrents with upward tendency.
According to the observations made by Lilienthal these currents form on the average an angle of 31/2 degrees with the line of the horizon.
Otto Lilienthal described the results of his numerous experiments in his pamphlet of the year 1889, entitled " The Flight of Birds as a Basis for the Art of Flying."
Shortly afterwards with the greatest zeal he again took up the practical attempts at flying which he had begun so long before. He had come to the conclusion that be could scarcely attain the solution of the problem of flight in bis study, but that he must take the knowledge be bad gained by observation and calculation out into the open air, to test with the wind, and in the element for which it was made, the apparatus constructed according to the theories be bad developed. Theorizing alone would never bring about success. Brooding over and calculating about it would not bring one to the desired goal. One must draw Lilienthal was right in pointing to the example of the bicycle to show how important practical experiments are in contrast to pure theory. Without doubt, our ancestors would have shaken their heads incredulously over the problem of the bicycle; it was first solved practically and now has come the theoretical solution. Of all the various methods of flying which nature shows us, sailing flight seemed the most worthy of imitation. It allows, as observation shows, the swiftest and most uninterrupted motion forward with a minimum of physical exertion. The solving of the mystery of this sailing-flight must therefore be the most important task of the flight technician. The apparatus used by the experimenter in resuming his attempts in the spring of 1891 had the shape of birds' wings when spread out. The cross-section through the wing lying in the plane of the direction of flight was curved parabolically; the surfaces of the wings comprised in the beginning 10 square metres; they decreased gradually on account of various changes and repairs to 8 square metres. [The width comprised at its greatest 7 m. by 2 m.] The framework of the wings was formed of willow-wood; the covering was made of sheeting covered with wax. The weight of the apparatus was about 18 kilos.
In order to hold the apparatus the arms are placed in two cushioned openings in the frame, the hands at the same time grasping two corresponding handles. In this way the wings are perfectly under control, and may be safely leaned on in the air. At first, of course, the flying experiments were made only from a low height and when there was no wind. Lilienthal made a spring-board on a large lawn in bis garden in Lichtefelde which could be made higher by degrees ; when first experimenting the board was but one metre high, later it was raised to two metres. On the spring-board he could take a run of eight metres in length. In spite of the jump the landing on the soft earth was gentle, so that a jump like this could be repeated many times without resulting in the least weariness or danger.
On having practised sufficiently the jumping off in this manner without wind, he selected another practising ground between Werder and Gross-Kreutz where several mounds of larger size, standing alone, made the experiments possible. Here it was found at once that in these experiments particular attention must be given to the wind then blowing. It is necessary when floating to move against the wind, for if one falls away from the wind, the pressure of the wind is felt, and the experimenter is not able to resist the one-sided effect. A vertical steering surface therefore had to be put on, thus enabling the apparatus to go against the wind.
On the grounds between Werder and Gross-Kreutz the jumping was done very frequently from greater heights and with winds of different force; a great deal of new experience was thus obtained. The final result was, that jumps of 2o-25 metres' length could be made from the highest jumping point there, from a height of 5 to 6 metres. This was done when there was no wind as well as with

winds of different force.
The difference showed itself particularly in the duration of the flight; the stronger the winds, the longer the journey in the air. The fact that landing when there is no wind is often a rather violent affair corresponds to what has been said, and it is therefore necessary to raise the wings a little in front shortly before landing, in order to mitigate the harshness of the shock and to prevent tilting over. This, however, refers only to flight when there is no wind; if the flight is against the wind, the landing on the ground is of an absolutely gentle nature.
The practising places not offering enough space to cover longer distances from greater heights, another spot, suitable for continuing the experiments, bad to be chosen in the following year, 1892. Such a place was found between Steglitz and Südende. The slopes here have a height of about 10 metres.
The experiments were made with an enlarged apparatus with a surface of 16 square metres and 24 kilos' weight, at a velocity of the wind up to 7 metres. He could take a start up to the jumping place, thereby obtaining a relative velocity of the air of 10 metres per second. Under these circumstances the first part of the sailing flight was almost horizontal; in its further course the line of flight sank considerably and declined rather suddenly at the end, as the wind loses a part of its force in the lower strata. In the most favorable case the length of the jump would be equal to S times the height of the jumping place above the landing point.
The surroundings of Berlin having a great dearth of good places for trying such flying experiments, Lilienthal constructed at Maihöhe near Steglitz a flying station of his own in the spring of 1893. A small declivity on this hill was arranged for a station for sailing flights. A tower-like shed was built, from the roof of which the flights were made, and which thus afforded a jumping place of 10 metres' height. The interior of the shed was used for storing the apparatus. The roof, which for the sake of a more secure start was covered with turf, sloped down, as did the declivity round the shed, towards south-west, west, and north-west. The apparatus showed a change as compared with that of previous years; it could be folded together, like the wings of the bat. It could, in consequence of this arrangement, be removed more easily and stored at almost any place.
It was only seldom, however, that the wind was favorable on the Maihöhe, and it was thus most important for the energetic continuing of the flying experiments that - in 1893 -Lilienthal succeeded in finding grounds which were suitable for his purposes in every respect. These are on the Rhinow mountains near Rathenow. Out of surrounding flat plough-lands there rises a chain of hills covered only with grass and heath, of up to 6o or even- as at the Gollenberg- up to So metres' height above the plain. The hills offer on every side descents, at an angle of from 10 to 20 degrees; and it is possible here to select a suitable position in whatever direction the winds make desirable, in order to glide above them through the air. The grounds really appear to be made for such flying experiments. The wind does not produce such gusts as at the flying tower at Steglitz, where one would always receive an irregular gust of wind from below, when passing the edge of the jumping place. Often enough this gust threatened to be fatal. Besides, this uniform acclivity permitted landing anywhere.
The wings which were used showed some changes as compared with those used previously. Their weight is 20 kilos, the complete weight just 100 kilos, the width from tip to tip 7 metres, the greatest breadth 2i metres, the complete surface 14 square metres, a size which appears to be fully sufficient. The wings are lowered when the experimenter runs downhill against the wind; at the proper moment he raises the supporting surfaces a little, so that they are about horizontal; then while poising in the air he endeavors by suitably changing the point of gravity to give to the apparatus such a position that it shoots quickly forward while lowering itself as little as possible. After a short time a great progress in the safe management of the apparatus could be observed. Very often sailing flights of 200 to 300 metre length were made from a height of 30 metres; a great additional progress consisted in the fact that he succeeded in directing the course of flight to the right and left.
Changing of the point of gravity is effected by stretching the legs in one or the other direction; even a slight change of the centre of gravity brings about at once a decline of the supporting surfaces towards the direction desired, the pressure of the air also increasing on this side. The direction of the course of flight then deviates to that side. Several times during the experiments the deviation

from the straight line of flight was carried so far that Lilienthal would at times return to the starting place.
A place which was very well suited for his experiments, and much more conveniently situated, was procured by Lilienthal in the spring of 1894, in Gross-Lichterfelde near Berlin; he caused a conic hill to be thrown up, which, having a height of 15 metres and at the basis a diameter of 70 metres, should admit of flying experiments in whatever direction the wind blew.
On this place he tried with good success his new flying apparatus, consisting of two surfaces arranged one above the other.
He had come to the point already that the experiments regarding sailing flight could be considered as being completed, and he proposed to take up the second task, viz., the imitating of the rowing flight of birds. A light machine, weighing in all only 40 kilos and supplying 2 1/2 horse-power for a short time (4 minutes), was constructed and tested several times. Lilienthal was therefore certainly justified in his words, when he declared in a lecture given in July, '96, in the Berlin trade exhibition buildings, that he had strong hopes of being able to further still more the development of the flying sport; but an accident put an untimely end to his endeavors on the 9th of August.
He had made, on that fatal day, a very extensive sailing flight on the Rhinow mountains, and thereby the special steering of the movable horizontal tail had proved to be very satisfactory; he then wanted to undertake a second flight of as long a duration as possible, and wanted to define the duration of the flight. As a rule, such flights would last from 12 to 15 seconds. He gave the timing-piece to his assistant. According to the statement of the latter, the flight was- up to half of the course of flight- almost horizontal; then the apparatus had suddenly tilted over in front, and had shot down rapidly from a height of 15 metres, being completely tilted over on the ground. The daring sportsman was dragged from the dèbris. His spine being broken, he died twenty-four hours later.
At present one cannot foresee what development may be in store for the principles laid down by Lilienthal in the art of flying: one thing however is certain, that not one of the numerous explorers and experimenters who have busied themselves with the problem of flying has done so much as Lilienthal to bring the difficult problem nearer its solution. It has therefore been justly emphasized, in the many accounts and debates which Lilienthal's experiments have called forth over the whole world, that he possessed three qualities in happiest union: He was first a thorough mathematician and physicist, and had given important contributions to the theory of flight by reason of his untiring observations and measurements of the resistance of the air to curved surfaces. Second, being a clever constructor, and especially as mechanical engineer, he was able to build the apparatus himself as he thought best fitted for imitating the flight of birds. Third, he possessed great daring and physical dexterity, so that he was in himself fitted for making experiments in flying.
Therefore his memory will be faithfully cherished by all those who have decided to labor on in the field of work which he made his own.