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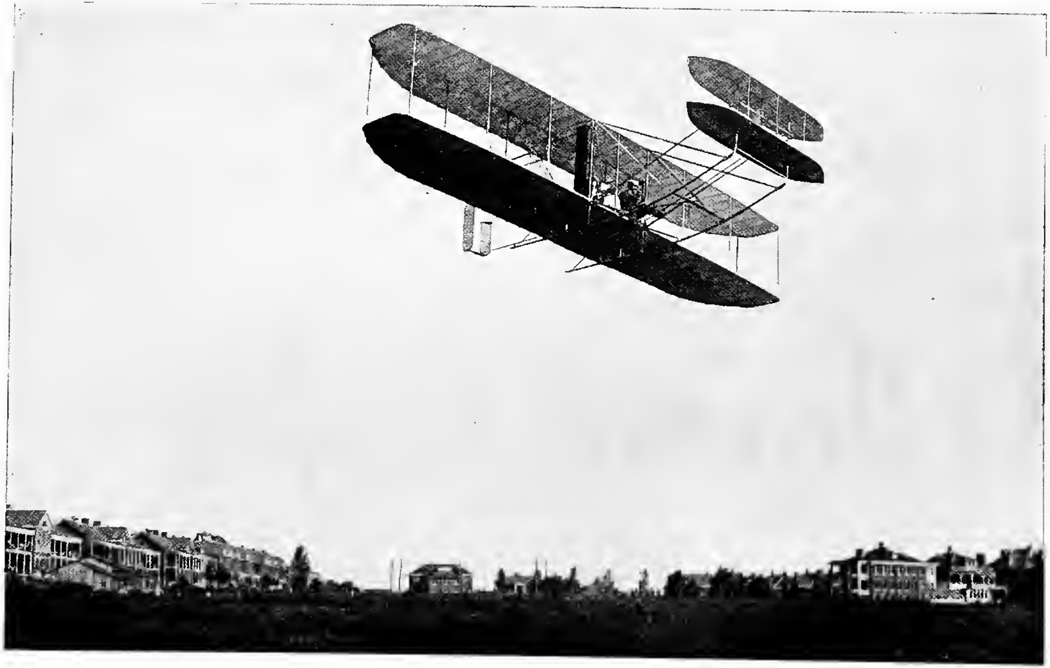

Orville Wright's Flight at Fort Myer, Va., Sept. 9, 1908.

THE CONQUEST OF THE AIR

OR THE
ADVENT OF AËRIAL NAVIGATION

BY

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PREFACE

The final conquest of the air by man finds no popular and, at the same time, scientific account, in English, of its accomplishment. While the rapid progress which is daily being made in aërial navigation necessarily renders any permanent record of the latest achievements impossible, yet the epoch when mechanical flight was demonstrated to the world seems opportune to chronicle the past and present status of the art and to forecast its future.

The physical conditions which prevail in the ocean of air being even more important to the aëronaut than the conditions on bodies of water are to the sailor, a knowledge of the former is of vital interest. Accordingly, it appeared appropriate that, at the outset, there should be given a description of the ocean above our heads, including the surveys and soundings which have been executed by the author during the past twenty years at his own observatory. These and similar meteorological researches, also undertaken elsewhere in the interest of pure science, now become of practical value to the aërial traveler.

The general facts concerning aërial navigation have been derived at first hand from authorities in Europe and America, the data are quoted from reliable sources, and the illustrations are reproduced from materials collected by the author or from the best pictures that have been published in foreign periodicals. Mr. Octave Chanute, of Chicago, whose knowledge of aëronautics is unsurpassed, has kindly consented to read the proof-sheets.

BLUE HILL METEOROLOGICAL OBSERVATORY,
MILTON, MASS.
April, 1909.

CHAPTER I

THE OCEAN OF AIR

Before discussing the methods of aërial navigation, it will be advantageous to consider the medium in which this must take place. The atmospheric ocean, at the bottom of which we live and move and have our being, presents analogies to the aqueous ocean upon which it rests. The lower portion of the former and the upper surface of the latter we know best, and it was to aid marine navigation that contiguous currents in both oceans were determined. By means of government expeditions, likewise, the depths, thermometric and hydrometric conditions of the oceans traversed by ships have been ascertained, but the ocean above our heads has been explored almost entirely in the interest of pure science and without the expectation of practical benefits. Apart from observations on mountain-tops, which give results that do not represent the conditions of the free air, the study of the high atmosphere has been undertaken systematically only within the past fifteen years and the fact that the atmosphere has no boundaries and can be pre-empted by no nation makes its exploration a truly international undertaking. This is being done through monthly kite and balloon ascensions under the auspices of the International Commission for Scientific Aëronautics, and the field of survey has lately been extended to Asia and Africa and the tropical and arctic oceans. The first meteorological records with kites were obtained at Blue Hill Observatory, near Boston, in 1894; the method was used at sea by the author in 1901, and three years later the temperature 10 miles above the American continent was ascertained by means of sounding balloons sent up under his direction. At the present time the aëro-physical observatory of the United States Weather Bureau is making daily kite flights and the extraordinary height of more than four miles has been attained. From all these sources many data are being accumulated which, while primarily intended to increase our knowledge of the physics of the globe, will also prove as useful to the aërial voyager as are the ocean pilot charts to the mariner.

Let us now compare, in a general way, the aërial and aqueous oceans. The former completely envelops the globe and rests lightly upon the other ocean that covers the greater portion of the crust with its tremendous weight. The atmosphere extends with diminishing density to an indefinite height, while the lesser depths of the sea are absolutely defined. Both oceans receive their heat from the sun, chiefly by radiation and absorption at their junction with each other, and therefore both become colder as we penetrate into them, so that near their superior and inferior portions, respectively, the lowest temperatures occur. Water is almost incompressible, and expands much less by heat than does the elastic air, consequently the currents in the latter are far more active and the cold in its higher regions results chiefly from cooling by expansion of the rising currents, whereas the cold at the bottom of the sea is the result of the descent of the denser water flowing from the poles. The rate of decrease of temperature with increasing depth in the water is faster than with increasing height in the air and in both is most rapid at the equator. There is a semi-diurnal tide in the lower air like that on the surface of the sea, but the irregular changes of pressure, amounting sometimes to one-fifteenth of the whole atmospheric pressure, produce the violent circulation in storms.

Such, then, are some of the similarities and differences between the superior and inferior oceans, on the border-line of which man has hitherto been content to live. While the seas have been completely mastered by man, at least superficially, the atmosphere offers to his ingenuity a medium that is equally navigable through a great thickness, and which dominates seas and mountains and so unites the nations. Obstacles to its use are the small supporting power which it affords and the violent commotions to which it is subject. Moreover, while a ship, by utilizing the resistance of the relatively stationary water on its side and rudder can deviate from the wind, a balloon resembles a submarine boat and if it possesses no motive power must drift with the current in which it is wholly immersed. However, as will be shown later, by taking advantage of a superposed or underlying air current blowing in an opposed direction, it may be possible for such an aërial craft to return to its starting point.

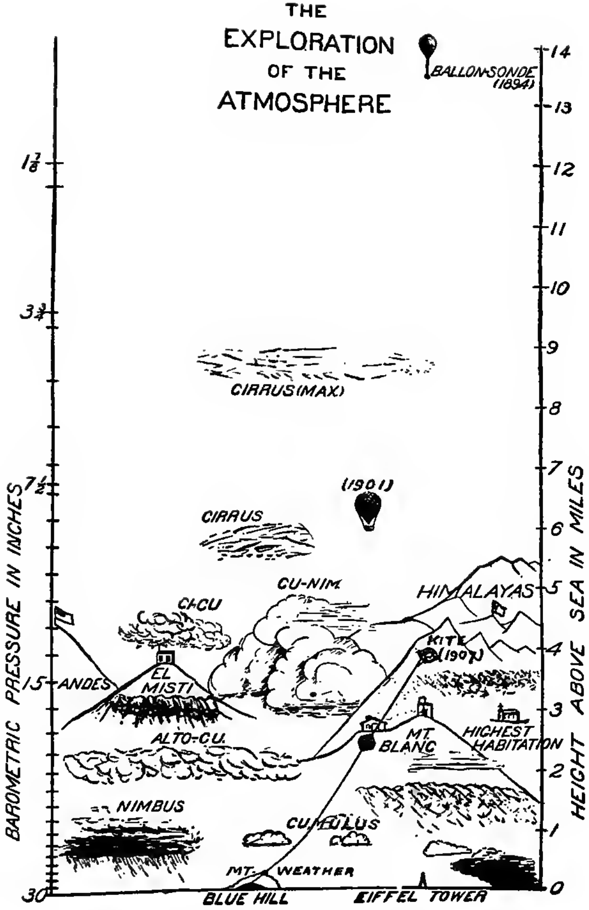

FIG. 1.—Comparative Altitudes.

An idea of how far the ocean of air has been explored is given in Fig. 1, which represents a vertical section of the atmosphere with the barometric pressures at the left which correspond to the successive heights marked on the right. The right-hand half of the diagram includes the eastern hemisphere and the highest mountains on the globe with the line of permanent snow and the greatest height to which man has climbed. The observatories on the Misti, in Peru, and on Mont Blanc, that had self-recording instruments, as well as the highest permanently inhabited place, are indicated. As regards the free air we see the relative levels reached by a kite and by man in a balloon and, at the top of the diagram, the height reached by *ballons-sondes,* which carry only self-recording instruments. The extreme height reached by such a balloon is 18 miles, which is more than twice as high as a human being can hope to attain, for the atmospheric pressure there is but a fraction of an inch of mercury, instead of 30 inches, which is the average density of the air that we breathe at sea-level. It may be perceived from the diagram that the pressure is reduced, generally speaking, about one-half for each three and a half miles of ascent, although the intervals diminish progressively upward. This rapid rarefaction makes it practically certain that the navigable portion of the air lies below seven miles, since here the atmospheric pressure becomes only a quarter of the normal. This lower portion of the atmosphere, which contains three-quarters of the whole mass, is unfortunately the region of storms and of the clouds which accompany them, for only occasionally are the cirrus, or ice-clouds, seen as high as nine miles. The winds which blow around our centers of low barometric pressure are replaced, above two or three miles, by the nearly constant, but rapid planetary circulation of the atmosphere, which, in temperate latitudes, is from west to east.

As was remarked, a great deal of information about the free air has been gathered by sending into the air instruments attached to kites and *ballons-sondes,* or sounding balloons. The latter are small balloons, now commonly made of sheet rubber, which carry barometers and thermometers especially designed to record very low pressures and temperatures, graphically and continuously. After the balloons reach their highest altitude they fall to the ground, where they are generally found and returned to the sender, and from the automatic records of their instruments the heights reached from moment to moment can be calculated, together with the temperature prevailing at these heights. Instruments lifted by kites show in more detail the conditions within two or three miles of the ground, and have the advantage of furnishing the data with greater certainty and nearly vertically over the station on the ground. The humidity can thus be measured and also the velocity of the wind, because the kite may remain stationary in any current at the will of the operator. Clouds, which float at different heights in the atmosphere, also afford a method of determining the direction and velocity of the air-currents. If the average heights of the different classes of clouds have been computed from angular measurements on a base-line, measurements of the apparent motion of these clouds will enable their true velocity, as well as their direction of motion, to be obtained at any time with sufficient accuracy. All these methods have been employed by the staff of the Blue Hill Observatory, obviating the necessity of ascending into the air themselves, and the results which will be given typify the general conditions prevailing over the United States. In order to obtain a continuous series of observations at a fixed height above sea-level, it is still necessary to make them on mountains, but, since these form a part of the earth's crust, such observations, even when made on an isolated peak, do not represent the conditions at an equal height in the free air, because the mass of the mountain influences the temperature and moisture

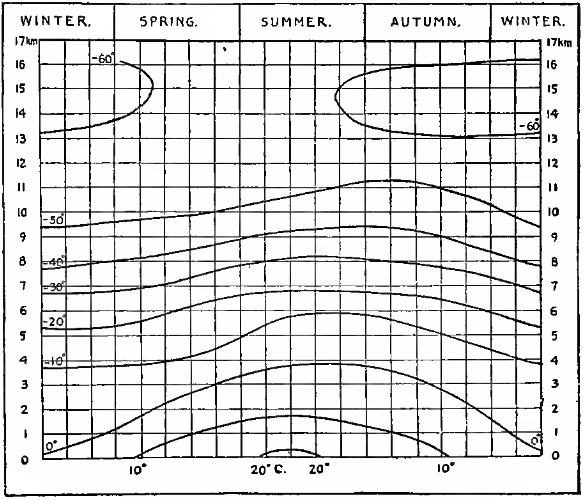

Fig. 2.—Annual Isotherms above St. Louis.

of the surrounding air and modifies the air currents which come in contact with it.

The temperature is of considerable importance to the aëronaut. It was said that, as we rise in the atmosphere, the temperature decreases, and, as a matter of fact, this occurs so rapidly that in an ascent of a few hundred feet the change in temperature corresponds to a displacement in latitude on the earth's surface of several hundred miles. Fig. 2 shows the height of the isotherms, or lines of equal temperature, at each season, obtained from the records of 62 ascensions of *ballons-sondes* at St. Louis. In this and the following diagrams the heights are expressed in kilometers, 16 kilometers being equivalent to 10 miles. The temperatures are given in Centigrade degrees, so that 0° C. is equivalent to 32° F., 20° C. to 68° F., and minus 60° C. to 76° F. below zero. The diagram shows that the line of 0° C. nearly touches the ground at St. Louis in the winter, but in midsummer rises 3,800 meters above it, the surface temperature being more than 20° C. It will be noticed that the curves of equal temperature preserve approximately the same form and distance apart, though they are somewhat more crowded above six kilometers, showing that the most rapid decrease of temperature is here. In fact, the rate of decrease nearly equals the adiabatic change for dry air, namely, 1° C. per 100 meters, or 1° F. per 183 feet, which is the cooling produced by the expansion of the air as it ascends, without the passage of heat to or from the air. Above 13 kilometers, however, the decrease of temperature is generally transformed into an increase of temperature with increasing height, though the height of this plane of inversion varies with the season. The cause and thickness of this warm stratum is unknown, but it was found to persist in Europe at 29 kilometers, or 18 miles, and it appears completely to surround the globe, being highest over the equator, and lowest in the arctic regions. However, it is only relatively warm, as the temperature is still some 70° F. below zero. The observations in the United States prove that in this warm stratum, between about 13 and at least 17 kilometers, there is nearly always a rise of temperature. For instance, on October 8, 1907, the temperature rose 9° C., between 14,500 and 16,000 meters. Taking another example, on November 6, 1907, the minimum temperature of —52° C.

was found at 9,700 meters, and increased nearly 2° C. within the next 300 meters, whereas on November 8, the minimum temperature of —63° C. occurred at 14,250 meters and rose 3° in the succeeding 1,130 meters, showing a change in level of the warm stratum of 4,550 meters within two days.

In the preceding diagram the seasonal effect of temperature is evident up to 10 kilometers, a height which has been attained by aëronauts, although the period of greatest warmth is retarded so that it here occurs in the autumn, as evinced by the maximum height of the isotherm of —50° C at that season. While the upper isotherm of —60° C. represents the lowest average temperature at any height, yet an extreme temperature of —70° C., or 110° F. below zero, was recorded in January, 1905, at a height of 14,800 meters, or about nine miles, this being one of the lowest natural temperatures ever observed in the air or on the earth, and even in the following July, —59° C., or 75° F. below zero, was registered at a slightly lower altitude. While the heights at which these temperatures were recorded probably can never be reached by human beings, yet, even at the altitudes to which aëronauts do ascend, it is intensely cold throughout the year, and this, combined with

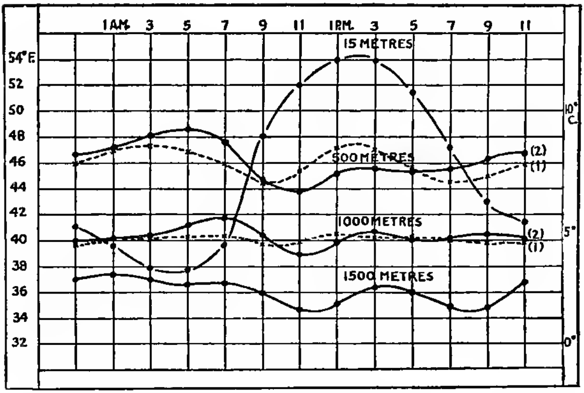

FIG. 3.—Diurnal Temperatures at Different Heights.

the rarefaction of the air, acts as a barrier to the attainment of greater heights.

But as aërial navigation will be carried on at comparatively low levels, it is necessary to examine in more detail the conditions which prevail in the lower mile or two of air. For many years these have been observed with kites at Blue Hill, and like the balloon observations, the results of their study by Mr. Clayton, meteorologist at the Observatory, are published in its *Annals,* and only some of them can be briefly stated here.

While it was seen that the seasonal and non-periodic changes of temperature are felt even at great heights, we shall find that this is not true for the average hourly changes which are exhibited in Fig. 3. Here the curves for three levels are plotted for every two hours with their values in Fahrenheit degrees on the left and in Centigrade degrees on the right. The curve for 15 meters elevation is for a station on the ground and shows the well-known diurnal range of temperature with the maximum in the early afternoon and the minimum in the early morning. The three other curves were obtained in the free air with the kite at 500, 1,000 and 1,500 meters (almost a mile), respectively; the dotted lines for the first two representing the results of a different method of reducing the data. They all show a diminished range of temperature from that at the ground, and in the curves at the highest levels the phases of the ground-curve are almost reversed, so that it is warmest at night and coldest about noon. Curves plotted for the relative humidity at these same heights show them to be nearly the inverse of the temperature curves, that is, the lower mile of air, excepting the surface-stratum, is, relatively,

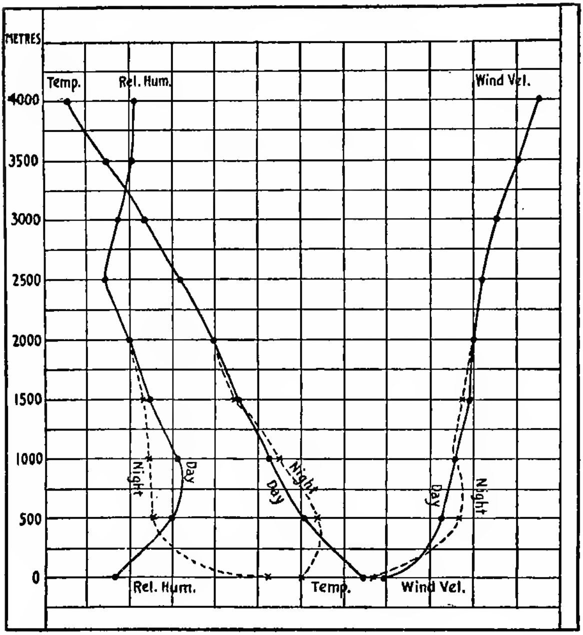

FIG. 4.—Vertical Gradients above Blue Hill.

warm and dry at night and cold and damp in the daytime.

The average vertical gradients of these two elements and also of wind velocity, up to a height of 4,000 meters, or two and a half miles, are plotted in Fig. 4. Here the lines inclining upwards to the right indicate increasing values and lines leaning to the left decreasing values, the dotted lines showing the nocturnal conditions. The temperature in the daytime decreases with height in the manner described, but at night is seen to increase up to the vicinity of 500 meters above the ground, on account of the nocturnal cooling of the soil by radiation and the consequent chilling of the contiguous air. The relative humidity increases in the daytime up to about 1,000 meters, and then falls to a minimum above the lower clouds at the height of a mile and a half. At night, however, it is already dry a quarter of a mile above the ground, because of the absence of ascending currents of air. It should be remembered that all these are average conditions, for strata are found at every height which differ greatly in temperature and humidity from the adjacent air, and are accompanied by abrupt changes in the direction and velocity of the wind.

Clouds constitute an obstacle to aërial navigation. If the aëronaut is enveloped in a cloud, or is between two strata which obscure both the earth and the sun or stars, he cannot tell where he is or whither he is going, and, moreover, moisture and, in greater degree, rain or snow overload his airship or disturb its balance. A balloon may be destroyed in the air by lightning and the up-rush of wind in the cumulo-nimbus, or thunder-shower clouds would jeopardize any airship caught in its embrace. The heights of the typical clouds, namely, nimbus, cumulus, alto-cumulus, cirro-cumulus, cumulo-nimbus and cirrus, which are much the same all over the world, were shown in Fig. 1. They tend to arrange themselves in distinct levels, with a maximum frequency between three-quarters of a mile and a mile and a quarter, and in other zones of frequency at regular intervals up to about six miles. We may place at eight miles the upper limit of the cirriform clouds, appearing to us on the earth as filaments, or as a thin veil through which the sun is faintly visible, but which are recognized as floating ice-crystals by aëronauts who have traversed them at a height of five or six miles. Rain or snow may fall from alto-nimbus, a uniform cloud-sheet more than a mile above the ground, but commonly comes from a ragged sheet of nimbus about half a mile high. In summer rain or hail also falls from cumulo-nimbus, whose towering top often extends into the cirrus region, whereas the thickness of the ordinary raincloud does not exceed two miles, and may be traversed usually by a balloon. On emerging from the darkness of the cloud into the bright sunshine which illumines the white cloud-billows, we have the scene represented in Fig. 5, which was photographed by the author, near London, at a height of 6,000 feet. The shadow of the balloon, surrounded by an aureole, is seen upon the cloud in the middle of the foreground. Since the average height of the different classes of clouds is

Fig. 5.—Sea of Clouds Seen from a Balloon.

known, the apparent motion of a particular cloud when observed at the ground gives to the aëronaut, wishing to start on a voyage, quite accurate information about the direction and speed of the air currents prevailing at that height, and in this way clouds serve as a wind gauge for the upper air.

Of all the meteorological elements the wind is the one with which aëronauts and aviators are most concerned. The relative change of velocity with height is indicated in Fig. 4, in which the rapid increase for a short distance above the ground is conspicuous. At night the acceleration in velocity is even more marked, attaining its maximum at the height of one-third of a mile. Higher up, in the daytime, the velocity increases slowly but at night decreases somewhat, except in winter, up to about 1,000 meters, or two-thirds of a mile. Above this height there is a steady increase of wind velocity with height and the rate of increase is greater above 2,500 meters, or a mile and a half. Fig. 6 shows bi-hourly wind velocities at Boston, 60 meters; Blue Hill, 200 meters; and in the free air at 500 and 1,000 meters. At Boston the wind velocity is distinctly greatest in the afternoon and least at night. On Blue Hill the diurnal change is small, but at 500 meters the period at the lower station is reversed, since the minimum velocity occurs in the afternoon and the maximum at night, and at 1,000 meters there are indications of a double maximum in the afternoon and at night and minima both in the morning and afternoon. Therefore, between 300 and 500 meters the wind velocity during the night and early morning is considerably greater than for heights immediately above or below. On the scale of wind velocity, one meter per second corresponds to two and one-quarter miles per hour. With a high baro-

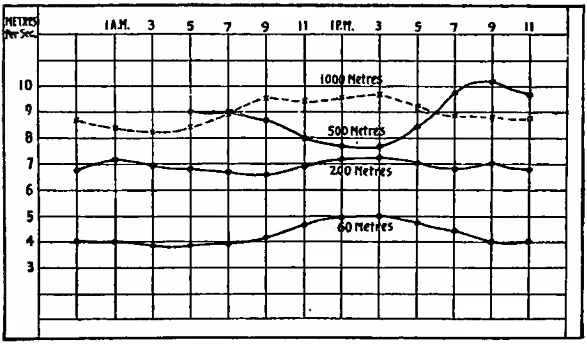

Fig. 6.—Diurnal Wind-Velocities at Different Heights.

metric pressure at the ground and in clear weather, the wind velocity increases slowly with altitude, but with a low barometer and in cloudy weather its velocity increases rapidly with altitude, especially near the strata of lower cloud.

Near the ground the wind is more gusty on account of the obstacles it encounters, which are analogous to reefs in the sea. At night, however, because there are no ascending currents, the wind is much steadier than in the daytime, making night the most favorable time for aërial navigation of all kinds. The uniformity of temperature, also, and the absence of intermittent sunlight through clouds, combine to make it possible at night to maintain a balloon at a constant level with small loss of gas. A suitable height in the daytime, unless a strong westerly wind is sought, lies above the cumulus clouds at the height of about a mile, but at night it is not necessary to rise so high, and in summer a region of relatively little wind is found at a height of about three-quarters of a mile, where it is also warmer and drier than in the daytime or at the ground. Over the open sea the diurnal change in wind velocity is very small and the velocity increases more slowly with height than immediately over the land.

At greater heights the wind can best be determined from clouds, measured as already stated. By such measurements at Blue Hill the average increase in velocity between 2,000 and 12,000 meters (1¼ to 7½ miles) was found to be nearly one mile per hour for each 100 meters, or 330 feet, of ascent, being rather more than half a mile per hour in summer and a mile and a half in winter.

The actual velocities between the heights of half a mile and five miles were as follows:

Height in Miles		0.5	1 2	2.5	4.7	5.0
Velocity in Miles per Hour	Summer	16	18	23	31	52
	Winter	19	32	47	108	119

In considering this rapid increase of velocity with height it must be remembered, also, if it is a question of the resistance of a body to the air, that its pressure varies as the square of its velocity; so that doubling the velocity quadruples the pressure. Consequently, in augmenting a velocity from 19 miles to 119 miles per hour, which is the average speed of the currents in winter at the height of five miles, the pressure is increased from one pound to 43 pounds per square foot.* This is at sea-level, but at the altitude of five miles, owing to a diminution to three-eighths in the density of the air, the actual pressure upon a body having one square foot of flat surface exposed to a wind of 119 miles per hour would be reduced to 16 pounds. It is obvious, therefore, that the supporting power of the air is reduced in the same ratio, and since the resistance to propulsion through the air against head winds increases faster than their density diminishes, it follows that neither aëroplane nor dirigible balloon can be operated efficiently higher than is necessary to overcome the irregular conditions at the earth's surface. A balloon moving with the wind experiences but slight resistance, whereas a self-propelled apparatus which might be capable of traveling 10 miles per hour in still air would remain stationary, as regards the earth, when it encoun-

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*On Blue Hill an extreme velocity of 88 miles per hour during five minutes has been recorded in 20 years, which, according to the latest formula for converting velocity into pressure on a normal surface ($P=v^2 \times .003$) gives a pressure of 24 pounds per square foot. During the first four years of observation a self-recording pressure-plate was in operation, and on tered a contrary wind of 10 miles per hour, and yet there would be actually blowing against it the wind of 10 miles per hour, whose pressure was a third of a pound upon each square foot of surface normally exposed. If the machine could travel 20 miles per hour and the natural wind blew at half this rate against it, the machine would advance at the rate of 10 miles and would sustain a pressure of about one and a quarter pounds per square foot, the pressure increasing as the square of the velocity of the impinging air Although at Blue Hill the average wind velocity is greatest in March and least in August, at a height of two miles each of these extremes occurs about two months earlier than they do near the ground. Consequently, in this latitude, the months of June and July appear to be the most favorable season for self-propelled aërial craft. Assuming 18 miles per hour to be the highest

two occasions pressures of over 43 pounds on the square foot were registered, while the corresponding velocity during five minutes was only 85 miles per hour instead of 119 miles, as the pressure would indicate. This seems to show that the extreme pressures are of very short duration, perhaps lasting only a few seconds, and that the frequency and intensity of gusts is greatest at high velocities.

average wind in which a dirigible balloon can be operated, such a balloon might be used 55 per cent. of the hours during the winter, up to a height of 600 feet above Boston, and 75 per cent. of the hours during the summer.

It is generally assumed that the wind blows horizontally, and our ordinary anemometers measure only the horizontal component. A few years ago an instrument for recording the vertical component was in use at Zi-Ka-Wei, China, and on the Eiffel Tower in Paris, which showed the existence of both upward and downward currents. In 1891 such an instrument was exposed 30 feet above the tower of the Blue Hill Observatory, and observations were made during several months. Upward currents aggregating one thousand feet per day were recorded, due chiefly to the deflection of the horizontal wind on striking the hill, since the vertical wind was roughly proportional to the amount of horizontal wind, but it was also related to the heating of the hill by the sun, being strongest in clear weather. Downward currents were seldom registered, proving that, though they undoubtedly exist, their velocity was too small to effect the fans of the anemometer. That these vertical currents may extend to considerable heights is shown by the production of cumulus clouds, under which kites have demonstrated the existence of strong ascensional currents. The wave-like appearance of the higher clouds is also evidence of undulatory movements which may extend downwards to the earth, and cause rhythmical oscillations of the barometer. We are not yet prepared to say to what extent these upward currents may be utilized to lift aëroplanes, and the theory that the soaring bird is always sustained by them has not yet been generally accepted.

The change in wind direction with increasing height, as indicated by the kites, is normally to the right when the velocity increases with altitude on account of the effect of the earth's rotation, but when the influence of the barometric gradient at the surface is no longer felt, a westerly current is found, no matter what may have been the direction of the wind at the earth's surface. Usually the change is quite abrupt, but sometimes the direction alters gradually with height until the currents become almost diametrically opposed to those below. The same law for

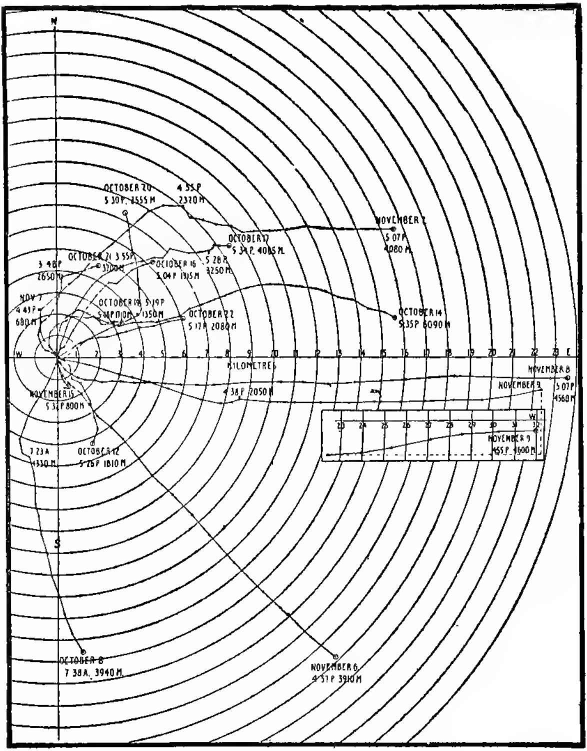

Fig. 7.—Courses of *Ballons-Sondes* from St. Louis.

change of wind direction was shown by the *ballons-sondes* sent up from St. Louis, of which a good many were watched by a surveyor's transit until they disappeared at a height of about two and a half miles, and two were seen up to nearly four miles. The azimuth and angular elevation, when combined with the height recorded by the barometer which was carried by the balloon, permitted its change of direction at various levels, as well as the speed, to be calculated. The wind direction generally shifted to the right with increasing height for winds coming from the south and to the left for northerly winds, until, at the height of two miles, it blew slightly from the north of west with a velocity of about 19 miles per hour in May and 39 miles per hour in November. Since these data agree with those got from the kites at Blue Hill, it follows that the upper air currents over the interior of this continent do not differ from those above the Atlantic coast.

In Fig. 7 the directions and velocities of the balloons which were thus observed by Mr. Fergusson, of the Blue Hill staff, during October and November, 1907, are projected upon the ground. The concentric circles show the distance in kilometers from St. Louis, eight kilometers being equal to five miles, and the points on the courses of the balloons give the position at the time of observation with the transit, these observations being usually made every minute. The disappearance of each balloon is indicated by a circle at the end of the course when the time and altitude, in meters, are marked. The tendency of most balloons to come into a westerly current at their maximum height is evident from the diagram.

To obtain the directions and velocities of the currents at greater heights with *ballons-sondes,* the direction of the place of fall of each balloon with respect to the starting point, and the time required to traverse this distance as recorded by the instrument, can be used. For any ascension, however, this gives only the average direction and speed at a height which may be assumed to be one-half the maximum height recorded.

The data for 64 *ballons-sondes,* which were sent up by the author from St. Louis at different seasons, represent the average movement of the air above the middle of the American continent. In the table which follows, the data are separated into four levels, the lowest at the bottom of the table including the balloons whose maximum heights were below 16,000 feet, the second, those in which the maximum heights were between

16,000 and 33,000 feet; the third, those between 33,000 and 49,000 feet, and the highest those above 49,000 feet. The heights are expressed in feet and the velocities in miles per hour, the directions being from whence the balloons came.

Average Drift of Ballons-sondes from St. Louis

No. of Ascensions	Mean of Max. Altitudes	Mean Altitude	Mean Velocity	Mean Direction From
13	52,000	26,000	43	12° N. of West
24	40,000	20,000	52	17° N. of West
16	25,000	12,000	40	14° N. of West
11	12,000	6,000	29	12° N. of West

It will be seen that the velocity of the air-currents increases up to the third level, and although the wind is already west at 6,000 feet, it turns slightly more to the north with increasing height. At the upper level the velocity decreases somewhat, and the direction turns back a little towards the west. The same peculiarities are noticeable in the air-movements for equal heights above Blue Hill, which were obtained from the observations of clouds, therefore the phenomena appear to be general in this country.

The above are average results and the individual courses of the balloons differ widely, although all traveled to the eastward of St. Louis, excepting one or two, which did not rise above the surface wind. Large differences occur from day to day in both the direction and velocity of the air currents. The greatest velocity was shown by two balloons on successive days in November, which reached extreme heights of about seven miles, and traveled at an average speed of 100 miles an hour, one 280 miles east, the other 255 miles south-southeast. As this is the average velocity in the upper and lower air-strata, the velocity at the maximum altitude in both cases probably much exceeded 100 miles an hour, but such velocities are shown by the measurements of the drift of cirrus clouds at Blue Hill to be not unusual in winter over the United States. An instance of apparently very low velocity at a great height occurred on October 16, 1907, when a balloon which reached a height of nearly 10 miles traveled only 28 miles towards the southeast although it was in the air three hours. In this case, which is illustrated in Fig. 7, we know from observations of the balloon that it was moving toward the northeast with a velocity of 30 miles an hour at the height of three-quarters of a mile. The direction was then seen to become easterly and its speed to diminish. At the end of 10 minutes the balloon had risen a mile and a quarter, and was four miles northeast of its starting point. For the next two hours and a half the balloon, at a high altitude, probably traveled in a general southeast direction at the rate of only 15 miles an hour, until it sank into the lower current, which again carried it a short distance northeast, and there it landed, 28 miles southeast of St. Louis.

While a balloon with no motive power must drift with the current in which it floats, it has been seen that by properly utilizing the different air-currents, its course can in some degree be controlled. For example, by rising a few miles into the air in temperate latitudes, a current from a general westerly quarter may always be found, no matter what was the direction of the surface wind. In the tropics, near the coast and at sea, above the permanent northeast and southeast trades the counter-trades blow, respectively, from the southwest and northwest. As some doubt had been cast upon this phenomenon, an expedition was sent in 1905, jointly by Monsieur Teisserenc de Bort, the distinguished French meteorologist, and the author, to explore the atmosphere above the tropical Atlantic. Pilot balloons, dispatched from the islands of Teneriffe and St. Vincent, were observed with theodolites at the ends of a base-line, and in this way the heights at which the balloons changed direction could be ascertained. Later the balloons were sent up from the yacht itself, which steamed after

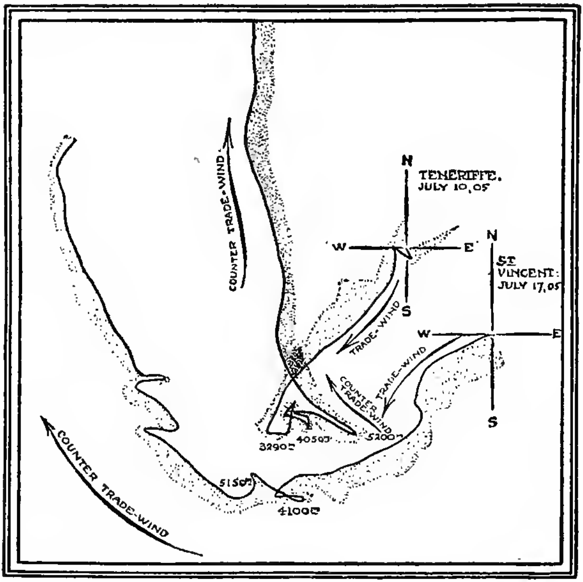

Fig. 8.—Trade and Counter-Trade Winds.

them, measurements being made of their angular elevation. The observations which are plotted in Fig. 8, prove conclusively the existence of the upper counter-trade. The courses of the balloons are represented as if projected upon the surface of the sea and show that the northeast trade-wind extended only to the height of 3,200 or 4,000 meters, and then gradually turned into a southerly current which, higher up, came from the southwest. The width of the dotted band represents approximately the varying velocity of the trade and counter-trade. Similar proofs of the northwest counter-trade, which is superposed on the southeast trade wind, south of the equator were obtained by the same expedition during the following year, but the above suffices to show that it would be possible for an aëronaut in an ordinary balloon to start from the African coast, or from some of the islands in the trade-wind region, and, after drifting towards the southwest, to rise a few miles into the current, which would carry the balloon north and eventually northeast back to land. Nevertheless it does happen in certain atmospheric situations over the tropical north Atlantic that the winds from a general northwesterly direction inshore to a considerable distance on most sun mer afternoons, while above it the westerl wind prevails throughout the day, affording means of sailing beyond the coast in the morr ing and returning with the lower wind in th afternoon. This method was employed b John Wise, the American aëronaut, more tha fifty years ago. In the same way use ma be made of other local winds such as thos which blow up the valleys in the daytime an downwards at night.

Consequently we see that while an aërc stat (which is the only aërial craft not sel propelled) cannot, like a ship, sail at a angle to the wind, except by the cumbersom device of towing a "deviator" through th water, yet in many cases, by the facility of as cending and descending into other current the aërostat may change its course and eve return to the starting point. Dirigible bal loons, like low-powered steam-vessels, may als profit by the prevailing winds, and, therefore to ascertain the meteorological conditions which balloons and aëroplanes must encounter at different heights, places, and times, such knowledge as is outlined in this chapter will be eagerly sought.

Meteorology and aëronautics are mutually dependent upon one another. The exploration of the air will give better knowledge of the meteorology of the upper regions and will result, perhaps, in a more complete utilization of such natural forces as solar energy and wind. The sea, at present the great medium of international communication, is navigable only on its surface, except to a very limited extent, whereas the aëronaut can use a vast height of atmosphere. Oceans separate continents and mountains form natural boundaries between nations, but the atmosphere binds them all together in its embrace. Therefore, it appears certain that man will not rest until he has completely conquered the ocean of air by opening its domain to his activities.

CHAPTER II

THE HISTORY OF AËROSTATION

FROM the earliest times the vast realms which extend above us have tempted man's ambition and efforts. In the 4th century B.C., Archytas of Tarentum, a Pythagorean philosopher, invented a wooden dove which is said to have risen into the air and really flown. During the subsequent centuries there were obscure legends of men who attempted to fly, but not until the 13th century do we find anything so definite as the proposition of the English friar, Roger Bacon, "to fill a large, hollow globe of copper, wrought extremely thin, with ethereal air or liquid fire, and to launch it from some elevated point into the atmosphere where it will float like a vessel on the water." Bacon also wrote: "there may be made some flying instrument, so that a man sitting in the middle of the instrument and turning some mechanism may put in motion some artificial wings which may beat the air like a bird flying."

Leonardo da Vinci in the 16th century revived Bacon's last idea and his knowledge of human anatomy appears in the drawings which he left of a flying machine with jointed wings, which contracted on the upward stroke and expanded on the downward, and were intended to be driven by a man's legs and arms.

Both these schemes were proposed in a somewhat more definite form at the end of the 17th century. In 1670 the Jesuit, Francis Lana, conceived that a vessel exhausted of air would weigh less than when full. He therefore proposed to construct four globes of copper each 20 feet in diameter and so thin that they would weigh less than an equal bulk of atmosphere when they were exhausted of air. To these globes a boat was attached, having also a mast and sail with which Lana supposed the aëronaut could direct his course. The apparatus is represented in Fig. 9, which is copied from *Prodromo all' Arte Maestra del P. Francesco Lana.* The principle of the hollow globes was correct and only the difficulty of providing a perfect vacuum and the weight of the globes thick enough to withstand the external pressure of the air prevented Lana from achieving success. It may be regarded therefore as the prototype of the modern balloon.

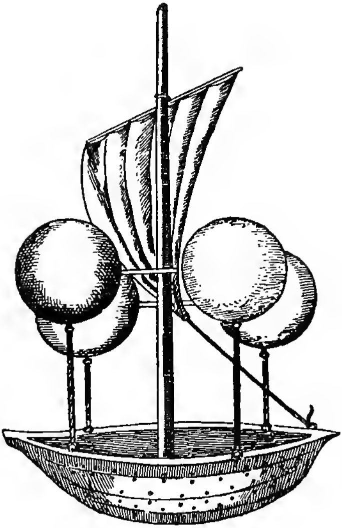

FIG. 9.—Lana's Airship.

The other device, which typifies the heavier-than-air flying machine, was constructed in 1678 by a French locksmith named Besnier, namely two pairs of wings, which opened and shut and oscillated about his shoulders by the action of feet and hands. This machine, as illustrated in the *Journal des Sçavans,* is shown in Fig. 10. Besnier did not pretend that he could rise from the ground or make a long flight, but he is said to have made some use

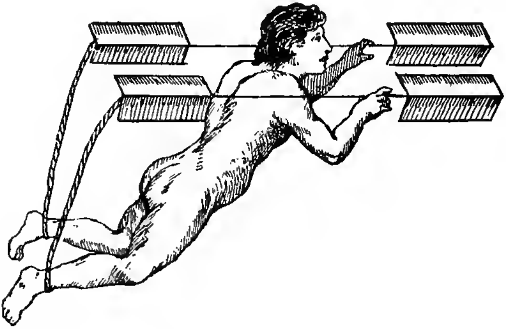

FIG. 10.—Besnier's Flying-Machine.

of these wings to raise himself from one height to another and then to descend across such an obstacle as a river.

According to many reports a Portuguese named Gusmao rose from Lisbon in 1709 in an airship, and his arrival in Vienna is gravely described in a contemporaneous tract published there and entitled: *Nachricht von dem Fliegenden Schiffe so aus Portugal den* 24

Juni in Wien mit seinem Erfinder glücklich ankommen.

In 1755 Father Galien of Avignon published a book called *L'Art de naviguer dans les airs* in which he enunciated clearly the theory of rarefied air-balloons. He states that balloons filled with the air of the upper regions would float in the denser air below, but does not explain the method of filling. The time was now ripe for the invention of the balloon, although other attempts at mechanical flight intervened, notably the flying chariot of Blanchard, who afterwards became a distinguished aëronaut.

After Cavendish had shown in 1766 that hydrogen gas is much lighter than air and Cavallo, who also lived in London, had filled soap-bubbles with hydrogen, the principle of the balloon was demonstrated. It was reserved, however, for the Montgolfier brothers, paper makers of Annonay, near Lyons, to make a practical application of the principle. After some preliminary experiments, a public trial was made on June 5, 1783, and a paper balloon, weighing with the wooden frame around its mouth, 300 pounds, and filled with 22,000 cubic feet of hot air, produced by burning straw, rose more than a mile into the atmosphere. This experiment, the first step in the conquest of the air, excited great interest and was repeated in Paris two months later by Charles and Robert, who, however, used the newly-discovered hydrogen gas instead of hot air. Benjamin Franklin, then United States Minister to the Court of France, took great interest in the experiments, and amid the pressure of diplomatic and social duties he found time to investigate personally this new invention, of which he at once appreciated the possibilities. Franklin's letters to Sir Joseph Banks, president of the Royal Society of London, give a complete and accurate account of the beginning of aërial navigation, enlivened with the humor and speculation characteristic of the writer. Since these letters are little known, portions of some of them are reprinted from the original press copies owned by the author.

THE FIRST HYDROGEN BALLOON.

PASSY, Aug. 30, 1783.

On Wednesday, the 27th Instant, the new aerostatic Experiment, invented by Messrs.

Montgolfier, of Annonay, was repeated by M. Charles, Professor of experimental Philosophy at Paris.

A hollow Globe 12 feet Diameter was formed of what is called in England Oiled Silk, here *Taffetas gommé*, the Silk being impregnated with a Solution of Gum elastic in Lintseed Oil, as is said. The Parts were sewed together while wet with the Gum, and some of it was afterwards passed over the Seams, to render it as tight as possible.

It was afterwards filled with the inflammable Air that is produced by pouring Oil of Vitriol upon Filings of Iron, when it was found to have a tendency upwards so strong as to be capable of lifting a Weight of 39 Pounds, exclusive of its own Weight which was 25 lbs and the Weight of the Air contain'd.

It was brought early in the morning to the *Champ de Mars*, a Field in which Reviews are sometimes made, lying between the military School and the River. There it was held down by a Cord till 5 in the afternoon, when it was to be let loose. Care was taken before the Hour to replace what Portion had been lost, of the inflammable Air, or of its Force, by injecting more.

It is supposed that not less than 50,000 People were assembled to see the Experiment, The *Champ de Mars* being surrounded by multitudes, and vast Numbers on the opposite Side of the River.

At 5 o'Clock Notice was given to the Spectators by the Firing of two Cannon, that the Cord was about to be cut. And presently the Globe was seen to rise, and that as fast as a Body of 12 feet Diameter, with a force only of 39 Pounds, could be suppos'd to move the resisting Air out of its Way. There was some Wind, but not very strong. A little Rain had wet it, so that it shown, and made an agreeable Appearance. It diminished in Apparent Magnitude as it rose, till it enter'd the Clouds, when it seem'd to me scarce bigger than an Orange, and soon after became invisible, the Clouds concealing it.

The Multitude separated, all well satisfied and delighted with the Success of the Experiment, and amusing one another with discourses of the various uses it may possibly be apply'd to, among which many were very extravagant. But possibly it may pave the Way to some Discoveries in Natural Philosophy of which at present we have no Conception.

A Note secur'd from the Weather had been affix'd to the Globe, signifying the Time & Place of its Departure, and praying those who might happen to find it, to send an account of its State to certain Persons at Paris. No News was heard of it till the next Day, when Information was receiv'd, that it fell a little after 6 o'clock, at Gonesse, a Place about 4 Leagues Distance, and that it was rent open, and some say had Ice in it. It is suppos'd to have burst by the Elasticity of the contain'd Air when no longer compress'd by so heavy an Atmosphere.

One of 38 feet Diameter is preparing by Mr. Montgolfier himself, at the Expence of the Academy, which is to go up in a few Days. I am told it is constructed of Linen & Paper, and is to be filled with a different Air, not yet made Public, but cheaper than that produc'd by the Oil of Vitriol, of which 200 Paris Pints were consum'd in filling the other.

It is said that for some Days after its being fill'd, the Ball was found to lose an eighth Part of its Force of Levity in 24 Hours; Whether this was from Imperfection in the Tightness of the Ball, or a Change in the

Nature of the Air, Experiments may easily discover. . . .

M. Montgolfier's Air to fill the Globe has hitherto been kept secret; some suppose it to be only common Air heated by passing thro' the Flame of burning Straw, and thereby extreamly rarefied. If so, its Levity will soon be diminish'd, by Condensation, when it comes into the cooler Region above. . . .

P. S. I just now learn, that some observers say, the Ball was 150 Seconds in rising, from the cutting of the Cord till hid in the Clouds; that its height was then about 500 Toises, but, being moved out of the Perpendicular by the Wind, it had made a Slant so as to form a Triangle, whose base on the Earth was about 200 Toises. It is said the Country People who saw it fall were frightened, conceiv'd from its bounding a little, when it touched the Ground, that there was some living Animal in it, and attack'd it with Stones and Knives, so that it was much mangled; but it is now brought to Town and will be repair'd.

The great one of M. Montgolfier, is to go up, as is said, from Versailles, in about 8 or 10 Days. It is not a Globe but of a different Form, more convenient for penetrating the Air.

It contains 50,000 cubic Feet, and is supposed to have Force of Levity equal to 1500 pounds weight. A Philosopher here, M. Pilâtre du Rozier, has seriously apply'd to the Academy for leave to go up with it, in order to make some Experiments. He was complimented on his Zeal and Courage for the Promotion of Science, but advis'd to wait till the management of these Balls was made by Experience more certain & safe. They say the filling of it in M. Montgolfier's Way will not cost more than half a Crown. One is talk'd of to be 110 feet Diameter. Several gentlemen have ordered small ones to be made for their Amusement. One has ordered four of 15 feet Diameter each; I know not with what Purpose; but such is the present Enthusiasm for promoting and improving this Discovery, that probably we shall soon make considerable Progress in the art of constructing and using the Machines.

Among the Pleasanteries Conversation produces on this Subject, some suppose Flying to be now invented, and that since Men may be supported in the Air, nothing is wanted but some light handy Instrument to give and direct Motion. Some think Progressive Motion on the Earth may be advanc'd by it, and that a Running Footman or a Horse slung and suspended under such a Globe so as to have no more of Weight pressing the Earth with their Feet, than Perhaps 8 or 10 Pounds, might with a fair Wind run in a straight Line across Countries as fast as that Wind, and over Hedges, Ditches & even Waters. It has been even fancied that in time People will keep such Globes anchored in the Air, to which by Pullies they may draw up Game to be preserved in the Cool & Water to be frozen when Ice is wanted. And that to get Money, it will be contriv'd to give People an extensive View of the Country, by running them up in an Elbow Chair a Mile high for a Guinea, &c., &c.

B. FRANKLIN.

THE FIRST AËRIAL VOYAGE BY MAN

Performed by the Marquis d'Arlandes and Pilâtre de Rozier, Nov. 21, 1783, and represented in Fig. 11, reproduced from a contemporary print.

PASSY, Novr 22d, 1783.

. . . Enclosed is a Copy of the *Procès verbal* taken of the Experiment made yesterday in the Garden of the Queen's Palace *la*

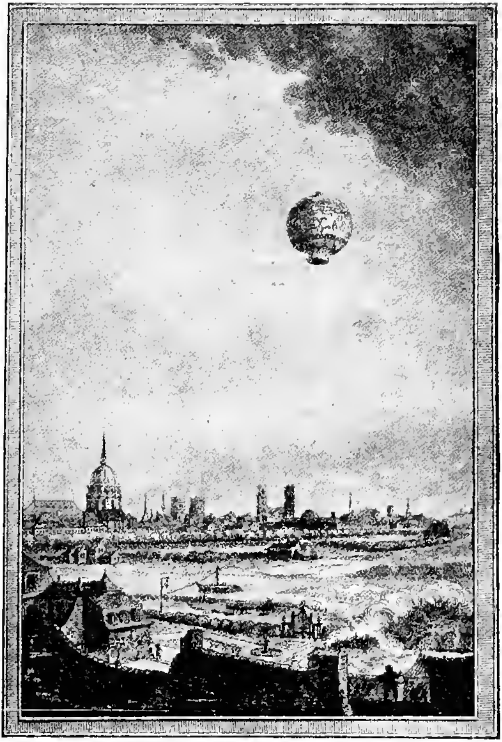

Fig. 11.—First Aërial Voyage.

Muette, where the Dauphin now resides, which being near my House I was present. This Paper was drawn up hastily, and may in some

Places appear to you obscure; therefore I shall add a few explanatory Observations.

This Balloon was larger than that which went up from Versailles and carried the Sheep, &c. Its bottom was open, and in the middle of the Opening was fixed a kind of Basket Grate, in which Faggots and Sheaves of Straw were burnt. The Air rarefied in passing thro' this Flame rose in the Balloon, swell'd out its sides, and fill'd it.

The Persons who were plac'd in the Gallery made of Wicker, and attached to the Outside near the Bottom, had each of them a Port thro' which they could pass Sheaves of Straw into the Grate to keep up the Flame, & thereby keep the Balloon full. When it went over our Heads, we could see the Fire which was very considerable. As the Flame slackens, the rarefied Air cools and condenses, the Bulk of the Balloon diminishes and it begins to descend. If those in the Gallery see it likely to descend in an improper Place, they can by throwing on more Straw, & renewing the Flame, make it rise again, and the Wind carries it farther. . . .

One of these courageous Philosophers, the Marquis d'Arlandes, did me the honour to call upon me in the Evening after the Experiment, with Mr. Montgolfier the very ingenious Inventor. I was happy to see him safe. He informed me that they lit gently, without the least Shock, and the Balloon was very little damaged.

This method of filling the Balloon with hot Air is cheap and expeditious, and it is supposed may be sufficient for certain purposes, such as elevating an Engineer to take a view of an Enemy's Army, Works, &c., conveying Intelligence into, or out of a besieged Town, giving Signals to distant Places, or the like.

The other Method of filling a Balloon with permanently elastic inflammable Air, and then closing it is a tedious Operation, and very expensive; Yet we are to have one of that kind sent up in a few Days. It is a Globe of 26 feet diameter. The Gores that compose it are red and white Silk, so that it makes a beautiful appearance. A very handsome triumphal Car will be suspended to it, in which Messrs. Roberts, two Brothers, very ingenious Men, who have made it in concert with Mr. Charles, propose to go up. There is room in this Car for a little Table to be placed between them, on which they can write and keep their Journal, that is, take Notes of everything they observe, the State of their Thermometer, Barometer, Hygrometer, &c., which they will have more leisure to do than the others, having no fire to take Care of. They say they have a contrivance which will enable them to descend at Pleasure. I know not what it is. But the Expence of this machine, Filling included, will exceed, it is said, 10,000 Livres.

This Balloon of only 26 feet diameter, being filled with Air ten times lighter than common Air, will carry up a greater Weight than the other, which, tho' vastly bigger, was filled with an Air that could scarcely be more than twice as light. Thus the great Bulk of one of these Machines, with the short duration of its Power, & the great Expence of filling the other will prevent the Inventions being of so much Use as some may expect, till Chemistry can invent a cheaper light Air producible with more Expedition.

But the Emulation between the two Parties running high, the Improvement in the Construction and Management of the Balloons has already made a rapid Progress; and one cannot say how far it may go. A few Months since the Idea of Witches riding thro' the Air upon a Broomstick, and that of Philosophers upon a Bag of Smoke, would have appeared equally impossible and ridiculous.

These Machines must always be subject to be driven by the Winds. Perhaps Mechanic Art may find easy means to give them progressive Motion in a Calm, and to slant them a little in the Wind.

I am sorry this Experiment is totally neglected in England, where mechanic Genius is so strong. I wish I could see the same Emulation between the two Nations as I see between the two Parties here. Your Philosophy seems to be too bashful. In this Country we are not so much afraid of being laught at. If we do a foolish thing, we are the first to laugh at it ourselves, and are almost as much pleased with a *Bon Mot* or a *Chanson*, that ridicules well the Disappointment of a Project, as we might have been with its Success. It does not seem to me a good reason to decline prosecuting a new Experiment which apparently increases the power of Man over Matter, till we can see to what Use that Power may be applied. When we have learnt to manage it, we may hope some time or other to find Uses for it, as men have done for Magnetism and

Electricity, of which the first Experiments were mere Matters of Amusement.

This Experience is by no means a trifling one. It may be attended with important Consequences that no one can foresee. We should not suffer Pride to prevent our progress in Science.

Beings of a Rank and Nature far superior to ours have not disdained to amuse themselves with making and launching Balloons, otherwise we should never have enjoyed the Light of those glorious objects that rule our Day & Night, nor have had the Pleasure of riding round the Sun ourselves upon the Balloon we now inhabit.

B. FRANKLIN.

THE SECOND AËRIAL VOYAGE BY MAN

Ascension of Messrs. Charles and Robert, Dec. 1, 1783, of which a representation from a contemporary print is given in Fig. 12.

PASSY, Dec. 1, 1783.

In mine of yesterday I promised to give you an account of Messrs. Charles & Robert's

FIG. 12.—Second Aërial Voyage.

Experiment, which was to have been made this Day, and at which I intended to be present. Being a little indispos'd, & the Air cool, and the Ground damp, I declin'd going into the

Garden of the Tuilleries where the Balloon was plac'd, not knowing how long I might be oblig'd to wait there before it was ready to depart; and chose to stay in my Carriage near the Statue of Louis XV. from whence I could well see it rise, & have an extensive View of the Region of Air thro' which, as the Wind sat, it was likely to pass. The Morning was foggy, but about one o'Clock the Air became tolerably clear; to the great Satisfaction of the Spectators, who were infinite. Notice having been given of the intended Experiment several days before in the Papers, so that all Paris was out, either about the Tuilleries, on the Quays & Bridges, in the Fields, the Streets, at the Windows, or on the Tops of Houses, besides the Inhabitants of all the Towns & Villages of the Environs. Never before was a philosophical Experiment so magnificently attended. Some Guns were fired to give Notice that the departure of the great Balloon was near, and a small one was discharg'd which went to an amazing Height, there being but little Wind to make it deviate from its perpendicular Course, and at length the Sight of it was lost. Means were used, I am told, to prevent the great Balloon's rising so high as might indanger its Bursting. Several Bags of Sand were taken on board before the Cord that held it down was cut, and the whole Weight being then too much to be lifted, such a Quantity was discharg'd as to permit its Rising slowly. Thus it would sooner arrive at that Region where it would be equilibrio with the surrounding Air, and by discharging more Sand afterwards, it might go higher if desired. Between One & Two o'Clock, all Eyes were gratified with seeing it rise majestically from among the Trees, and ascend gradually above the Buildings, a most beautiful Spectacle! When it was about 200 feet high, the brave Adventurers held out and wav'd a little white Pennant, on both sides their Car, to salute the Spectators, who return'd loud Claps of Applause. The Wind was very little, so that the Object, tho' moving to the Northward, continued long in View; and it was a great while before the admiring People began to disperse. The Persons embark'd were Mr. Charles, Professor of Experimental Philosophy, & a zealous Promoter of that Science; and one of the Messieurs Robert, the very ingenious Constructors of the Machine. When it arrived at its height, which I suppose might be 3 or

400 Toises, it appeared to have only horizontal Motion. I had a Pocket Glass, with which I follow'd it, till I lost Sight, first of the Men, then of the Car, and when I last saw the Balloon, it appear'd no bigger than a Walnut. I write this at 7 in the evening. What became of them is not yet known here. I hope they descended by Day-light, so as to see & avoid falling among Trees or on Houses, and that the Experiment was completed without any mischievous Accident, which the Novelty of it & the want of Experience might well occasion. I am the more anxious for the Event, because I am not well informed of the Means provided for letting themselves gently down, and the Loss of these very ingenious Men would not only be a Discouragement to the Progress of the Art, but be a sensible Loss to Science and Society. . . .

Tuesday Morning, December 2.—I am reliev'd from my Anxiety by hearing that the Adventurers descended well near l'Isle Adam, before Sunset. This Place is near 7 Leagues from Paris. Had the Wind blown fresh, they might have gone much farther.

P.S. Tuesday Evening. . . . I hear farther that the Travellers had perfect Command of their Carriage, descending as they pleas'd by letting some of the inflammable Air escape, and rising again by discharging some Sand; that they descended over a Field so low as to talk with Labourers in passing and mounted again to pass a Hill. The little Balloon falling at Vincennes shows that mounting higher it met with a Current of Air in a contrary Direction; An Observation that may be of use to future aërial Voyagers.

B. FRANKLIN.

To appreciate the ascent of man from the time that he possessed the means of rising freely in the air, we must remember that for centuries he was not only confined to the earth's surface but had not even climbed its high mountains, since not until 1787 did De Saussure reach the summit of Mont Blanc. As soon, however, as the long sought for means of rising without exertion into the air had been discovered men speedily availed themselves of it—namely, first of the Montgolfière or hot-air balloon, and then of the Charlière, or hydrogen balloon, and so rapidly was this done that before the close of the year 1783—the year that Montgolfier had produced his balloon—M. Charles ascended in a hydrogen balloon 9,000 feet above Paris.

The first persons in England who devoted themselves to aërial navigation were foreigners. Two of them were Italians, the philosopher Tiberius Cavallo, who already in 1782 had showed to a London assembly that soap-bubbles filled with hydrogen will rise, and therefore had almost anticipated the invention of the hydrogen balloon, and the diplomatist Vincent Lunardi, who made some daring balloon ascents in 1784. But the honor of making the first scientific balloon voyage is due to a Bostonian, Dr. John Jeffries. Dr. Jeffries graduated at Harvard College in 1763 and then practiced medicine in England, where he became a loyalist, and during the Revolution was with the British troops. In London he interested himself in aërostation, and, aided by the Royal Society, made a balloon ascent because, he said, " I wished to see the following points more clearly determined: first, the power of ascending or descending at pleasure, while suspended and floating in the air; secondly, the effect which oars or wings might be made to produce towards the purpose and in directing the course of the balloon; thirdly, the state and temperature of the atmosphere at different heights from the earth; and fourthly, by observing the varying course of the currents of air, or winds, at certain elevations, to throw some new light on the theory of winds in general." A French professional aëronaut named Blanchard had made three ascents in France and one in England, and Dr. Jeffries paid one hundred guineas to accompany Blanchard on his fifth ascent, which was made from London, November 30, 1784. The balloon rose nearly two miles, and descended safely in Kent after an hour and a half. Jeffries' meteorological observations compare favorably with those made until recently; indeed, for nearly a century there was little improvement in the apparatus. The decrease of temperature which Jeffries found, viz. 1° for 360 feet rise, and the decreasing humidity with height agree very well with later observations.

Jeffries and Blanchard undertook a more perilous voyage on January 7, 1785, from Dover across the Channel, landing in the province of Artois, after, so runs the announcement, " we were suspended and floating in the atmosphere two hours over the sea and forty-seven minutes over the land of France." The voyagers were cordially welcomed, and were entertained lavishly in Paris as being, Jeffries says, " the first who passed across the sea from England into France by the route of the air."

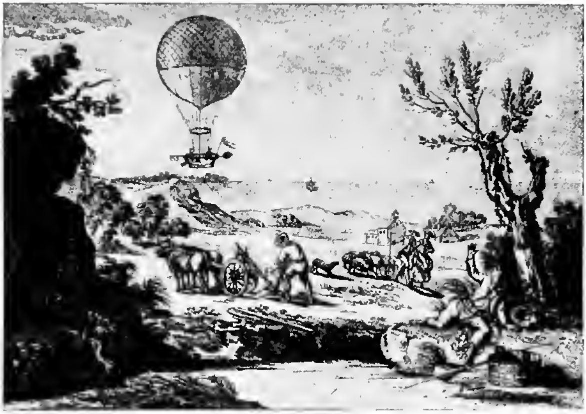

Fig. 13.—Jeffries and Blanchard Arriving in France.

Fig. 13, reproduced from an old print, shows the balloon reaching the land, and on one of the prints is this verse to celebrate the aërostatic alliance:

Deux Peuples divisées pour l'Empire des Mers,
Ne font qu'un aujourd'hui en franchissant les airs,
Présage fortuné de l'union sincère
Qui va regner entre eux pour le bien de la Terre.

Scientific observations in balloons, made in the early part of the last century, under the direction of the French Academy of Sciences, by Biot and Gay-Lussac, added materially to our knowledge of the constitution and properties of the atmosphere, but the first systematic work was done under the auspices of the British Association for the Advancement of Science from 1855 to 1865 by Welsh and Glaisher. In the course of these experiments Glaisher made his famous ascent to the height of what he claimed was seven miles, but which is now generally believed to have been below six miles Glaisher and his aëronaut Coxwell nearly lost their lives at this time by asphyxiation as depicted in Fig. 14, which is extracted from Glaisher's *Travels in the Air*.

In 1875 an attempt in France to make scientific observations at a great altitude resulted in the asphyxiation of Crocé-Spinelli and Sivel at a height of about 28,000 feet, notwithstanding the oxygen carried to assist respiration.

In 1890 the German Society for the Promotion of Aërial Navigation, aided by the German Emperor, began to collect observations in balloons by such methods as would insure accurate results, which previous aëronauts had

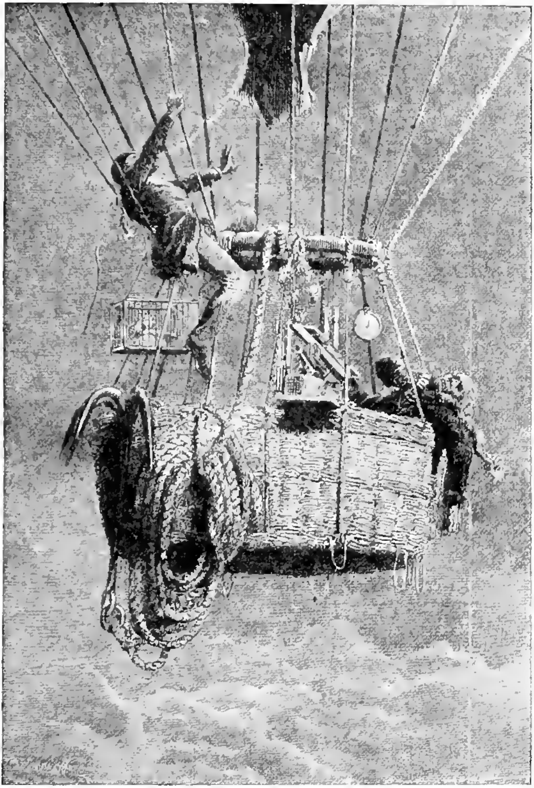

FIG. 14.—Highest Ascent of Glaisher and Coxwell.

not obtained. Professor Berson, who executed most of these ascensions, became known in Germany as "der höchste Mensch" (the highest man) because he had risen higher into the atmosphere than any other human being. In his highest ascent from Berlin on July 31, 1901, he was accompanied by Dr. Süring, and, aided by the respiration of oxygen, a height of about 34,000 feet was reached, which constitutes the present record, as seen in Fig. 1. A very large balloon is required, because to rise to such a height, where the atmospheric pressure is only a quarter of that at the ground, the balloon must be able to lift itself when partially filled with gas and, accordingly, the balloon, which could contain nearly 300,000 cubic feet, was two-thirds filled with hydrogen-gas, and carried ballast to the amount of 8,000 lbs. An ascent in this great balloon had been made from Charlottenburg, a suburb of Berlin, a few weeks before, by the same aëronauts, accompanied by Dr. von Schrötter, a physiologist.

Fig. 15.—Ascent of *Preussen.*

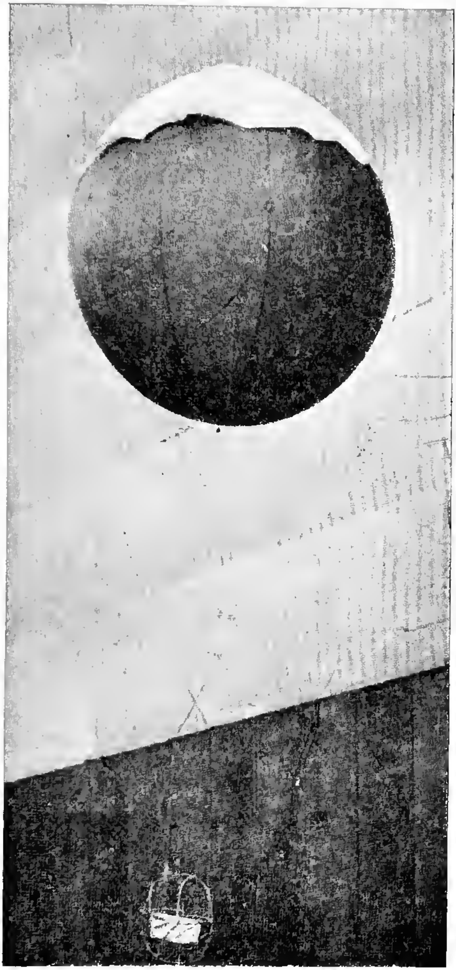

Fig. 16.—*Ballon-sonde* Rising from St. Louis.

The balloon in this case was filled with 247,000 cubic feet of illuminating gas, and reached a height of 24,000 feet. This ascension was witnessed by the author, and Fig. 15 shows the basket of the *Preussen,* as it rose with many bags of ballast clustered around it.

The French in 1893 found a method of bringing back supremacy to the native land of the balloon without risk of life or limb by the so-called *ballons-sondes,* which carried only self-recording instruments. These were ordinary balloons, which, after rising very high, drifted to a great distance as the gas escaped slowly. Dr. Assmann, a German, made an improvement by substituting small closed balloons of rubber which burst by the expansion of the hydrogen gas within, on reaching their extreme altitudes, and allow the instruments to be borne to the ground by parachutes. These balloons were mentioned in Chapter I, and Fig. 16 shows one of those employed by the author at St. Louis as it is rising.

With the invention of the balloon it was seen that captive balloons could render important service in warfare in determining the location of troops and in disseminating orders by signals, while free balloons would enable communication to be maintained across the enemy's lines. Fig. 17 from a contemporary print shows Coutelle in a captive balloon observing the Austrian troops at the battle of Fleurus in 1794. This method was also successfully practiced in 1861-2 during the American Civil War, while during the Franco-Prussian War of 1870-1 besieged Paris communicated with the outside world by means of free balloons. To-day a balloon corps is attached to the armies of all the great powers for the purpose of reconnoitering, communicating by

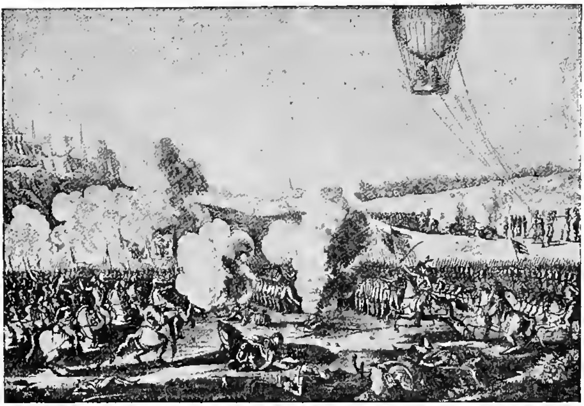

Fig. 17.—Captive Balloon at Battle of Fleurus.

FIG. 18.—Military Kite-Balloon.

wireless telegraphy or signaling with captive balloons. In the German army the Sigsfeld-Parseval captive balloon is used. This is anchored obliquely like a kite so that the wind, instead of driving it to the ground, tends to lift it higher and by blowing into an interior air-sack preserves its cylindrical shape. In Fig. 18 this balloon is being taken across a river by a boat. The dirigible balloon and the aëroplane are destined to be of still greater importance in military maneuvers.

Another use for the balloon is in exploration and one of the most conspicuous examples was the daring attempt of Andree ten years ago to reach the North Pole from Spitzbergen, by utilizing the prevailing southwest winds while he kept the balloon at the height of the drag-rope, and this he thought could be done for several weeks. No news was received after the first day or two and it is certain that Andree and his two companions perished miserably. Wellman with a motor-balloon proposes to discover the Pole, but it is significant that the plan is condemned by both arctic explorers and aëronauts. The Alps have now been crossed several times in a balloon, but the Mediterranean has hitherto proved a barrier.

Ballooning as a sport has recently come into favor, and dates from the foundation of the German Aëronautical Society in 1881, which was, however, organized mainly for scientific work. The French Aëro-Club was founded in 1898 and at once became a success in the land where the balloon originated and had always been popular, but it was the Paris Exposition of 1900 that gave an impetus to ballooning as a sport. During the Exposition 158 ascensions took place from the Aëronautic Park at Vincennes without the slightest accident. In the final long-distance race Count de la Vaulx landed in Russia after traveling 1,200 miles in 35 hours 45 minutes, which is the longest distance in a straight line that a balloon has gone. Balloon racing has been stimulated by contests for the Gordon Bennett Aëronauts' Cup to be awarded annually for the longest air-line distance without intermediate landings, and which has been competed for three times. In the first race in 1906 it was won by Lieut. Lahm, U.S.A., who went from Paris to England, a distance of 402 miles. As the winner was an American the scene of the contest in 1907 was transferred to St. Louis, and most of the balloons, by utilizing the upper westerly wind, traveled into the eastern states, as shown in Fig. 22. The winner was the German balloon *Pommern* with Herr Erbslöh as pilot, his assistant being Mr. Clayton of the Blue Hill Observatory, and they were only stopped by the coast of New Jersey, 872 miles from St. Louis. Last year several of the contestants starting from Berlin narrowly escaped death from falling to the ground or into the water, but the winner, Col. Schaeck, representing Switzerland, crossed the Baltic and landed in Norway after a voyage of 73 hours.

The first ascent by man in a balloon outside France, being the second time that hydrogen gas was used for the purpose, seems to have been in America, namely in Philadelphia, on December 28, 1783, when, through the initiative of Messrs. Rittenhouse and Hopkinson, a carpenter named Wilcox was lifted a short distance by several small balloons filled with hydrogen. The author, however, has been unable to obtain any particulars of the experiment, and what is usually called the earliest American ascension was made in Philadelphia on January 9, 1793, by J. P. Blanchard, the French aëronaut, who, it will be remembered, had already taken up the first American in England. After this, his 45th ascension, Blanchard was received by President Washington, who is reported to have witnessed it. The most famous American aëronaut is John Wise, who executed no less than 440 ascents in the forty years after 1835, and in one of them went from St. Louis to northern New York, a distance of 809 miles, in 20 hours, but afterwards lost his life in attempting another long voyage. St. Louis has not only been the starting point for the longest voyages, but probably the highest ascent in America was made there in 1887 by Prof. Hazen, who with three companions rose to a height of 15,400 feet.

The Aëro-Club of America, founded in 1905, is the parent of numerous local organizations to promote ballooning as a sport. There is, however, a growing tendency among the members to become interested in the dirigible balloon and the aëroplane, and the fact that gasoline motors are used both for aviation and automobiling tends to affiliate the aëro clubs with the older automobile clubs.

In Germany the various aëronautical organizations have been amalgamated in a national Union, while international aëronautic sport is regulated by a Federation, founded at Paris in 1905, and composed of representatives of the chief aëro clubs of the world Scientific and technical questions are considered by the Permanent International Aëronautical Commission, which was formed in 1900, and holds frequent meetings in Paris.

CHAPTER III

THE DIRIGIBLE BALLOON

No sooner was the balloon invented than attempts were made to render it independent of the wind and to go in any desired direction. We have seen that Benjamin Franklin, in describing the first balloon voyage by man in 1783, shrewdly suggested "that perhaps mechanic art may find easy means to give them [balloons] progressive motion in a calm and to slant them a little in the wind." A definite conception of the dirigible balloon, which was not realized in practice for a century, was embodied in a letter written to Benjamin Franklin on May 24, 1784, in which the writer, Francis Hopkinson of Philadelphia, proposes to make the balloon spindle-shaped and to drive it by a wheel at the stern. This wheel, it is explained, should consist of vanes or fans of canvas whose planes should be considerably inclined with respect to the plane of its motion, exactly like the wheel of a smoke-jack. Blanchard, of whom we have had occasion to speak several times, probably was the first in 1784 to apply a species of oars to the basket of a hydrogen balloon but without being able to effect any change in its direction. It was no doubt Blanchard also who induced our countryman, Dr. Jeffries, to try a similar appliance in their balloon-ascension in England later in the same year, one of the objects of this ascension being, according to Jeffries' account, already quoted, " to see the effect which oars or wings might be made to produce towards this purpose [ascending or descending at pleasure] and in directing the course of the balloon."

If the idea of rendering the balloon obedient to its helm by mechanical means dates from the invention of the balloon, that of utilizing favorable currents of air, which was described in Chapter I, is quite as old. While it is true that an aërostat floating freely in a current of air remains in a calm and, therefore, sails would be useless to change its direction, yet, if by a rope trailing on the ground, its velocity is checked, then it may be possible for a suitably arranged sail to alter the course of the balloon with reference to the direction of the wind. Also, since a vertical motion of the balloon produces a relative wind up or downwards, by means of oblique planes a lateral motion of the balloon, differing from the wind, may be obtained by its rise or fall. To avoid a loss of either gas or ballast it was attempted to produce a rise or fall of the balloon by means of paddles rotated by the aëronaut.

In 1784 General Meusnier, of the French Academy, made designs for a balloon which had the elements of the modern dirigible, namely, an elongated form and an envelope outside the gas-bag which could be filled with compressed air to maintain the shape of the bag. If more air was forced into the envelope the balloon would become heavier and descend, but if it was desired to rise, the air would be allowed to escape and the gas to expand to its original volume. Supposing there are currents at different heights which differ in direction, the one which corresponds most nearly with the desired route can be chosen, and to enter these currents the more easily, General Meusnier proposed to equip his balloon with vanes set obliquely on an axis which was to be turned by hand. This device * was virtually a screw-propeller and it was long before the screw as a means of propulsion in water had been suggested. The first elongated balloon was constructed by the brothers Robert, who had aided M. Charles with the first hydrogen balloon. Its envelope, made of varnished cotton, 52 feet long and 32 feet in diameter, was filled with pure hydrogen gas. Below hung a light wooden car, 16 feet long, from which six wings, in the form of oars, were to be worked to give the balloon motion, and a large rectangular oar at the rear acted as a rudder. The first trial was made in the Park of Saint Cloud on July 15, 1784, with the Duke of Chartres as a passenger, and a second trial in Paris was successful in producing a deviation of 22 degrees from the line of the wind.

Numerous airships of all kinds were projected in Europe during the next sixty-eight years, but few of them were of rational design and none of those tried achieved success. Although both the spherical and elongated balloon are claimed to have been invented and

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* Already described two months previously, by Hopkinson in America.

developed in France, yet, as we have seen, the idea of mechanical propulsion was suggested by Benjamin Franklin in 1783, and, according to the late Professor R. H. Thurston, a cigar-shaped balloon, driven by a screw-propeller, was patented in 1820 by Rufus Porter, an American. A model exhibited in New York between 1835 and 1840 was reported in the newspapers as flying rapidly and sustaining itself for a considerable time.

A real advance lay in the application of an artificial motor to the balloon, which was first done by Henri Giffard in 1852. His balloon had a gas-bag, pointed at either end, 144 feet long and 39 feet in diameter, and was driven by a screw-propeller turned by a three horse-power steam engine.

The small power, the lack of rigidity in the supports of the car and the deformation of the envelope itself, all contributed to the want of success of this balloon, which attained a speed of but seven miles an hour. Giffard, however, constructed a larger balloon and studied the plans for a gigantic one. During the Paris Exposition of 1878, he operated the largest captive balloon ever made, which could take up forty people at once. After the siege of Paris, Dupuy de Lôme, the eminent engineer, built an elongated balloon in which he preserved the form of the envelope, suspended rigidly the car, and avoided the resistance of the customary netting. Fearing to have fire near inflammable gas, Dupuy de Lôme employed eight men to work his screw-propeller, which gave this balloon a less speed than that of Giffard.

The dirigible balloon of Gaston Tissandier in 1883, in which the power was furnished by an electric storage battery, marked another step forward, but, although the speed attained was greater than that of his predecessors, it was not sufficient to bring the balloon back to its starting point.

The problem of the dirigible balloon was now taken up by the French War Department, and at the Central Establishment for Military Aëronautics at Chalais-Meudon elaborate experiments were carried out by Captain Charles Renard upon the resistance of the air to different bodies, the strength of materials, and the weight of motors. In 1884, just a century after the first elongated balloon had tried to overcome the wind, the balloon the *France,* designed by Captain Renard and his collaborator, Lieutenant Krebs, accomplished the unprecedented feat of returning to its starting point. During the ensuing year, this balloon, which attained a speed of about fourteen miles per hour, was able to return to its house at Chalais-Meudon five out of the seven times that it was tried, which were days of light winds. Fig. 19 shows the *France* as it appeared over Paris on September 22, 1885. This balloon embodied the best features of its predecessors. It was elongated and contained the *ballonet* of Meusnier; adopting the ideas of Dupuy de Lôme, the net was replaced by a close-fitting cover-

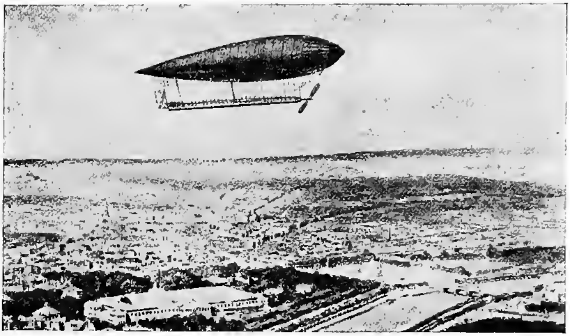

Fig. 19.—The *France* over Paris.

ing with crossed suspension cords and the propeller and rudder were large; and, following Tissandier's example, an electric motor was used. The novelties were the unsymmetric form of the envelope, with the large end in front, which gave stability of motion, the division of the *ballonet* into compartments, and the great length of the car, which enabled it to be brought up near the envelope, thereby diminishing the resistance due to the cordage. But the greatest improvement was the employment of a nine horse-power motor, which was much more powerful than any hitherto used in a balloon, and which, owing to a new storage battery invented by Captain Renard, had the unprecedented lightness of 100 pounds per horse-power. The length of the gas-bag was 165 feet, the diameter 27 1-2 feet, and the propeller, placed in front of the car, counterbalanced the weight of the rudder behind.

We now come to the modern dirigible balloon, in the success of which the chief factor has been the vast increase in efficiency and the decrease in weight of the gasoline motors developed by the automobile makers. The conditions necessary for a dirigible balloon were formulated by the late Colonel Renard, who was the best authority on the subject, as follows:—

1. An elongated form, similar to that of a boat.

2. Maintenance of shape by means of an internal sack, or *ballonet,* which permits loss of gas to be replaced by air.

3. Completion of the longitudinal stability, already partially secured by the *ballonct,* by a rigid suspension of the car.

4. A propeller of suitable size, driven by as powerful a motor as is consistent with weight.

5. A rudder at the rear, permitting changes of direction.

For a balloon to be dirigible in all directions it is necessary that its own speed, relative to the ground, should be greater than that of the average winds in which it must operate. Evidently, then, a balloon will be dirigible on certain days and not on others, whatever is its proper speed, and it will be more often dirigible in proportion as its speed is greater. According to observations 100 feet above a plateau near Chalais-Meudon, in the neighborhood of Paris, the wind is less than

22 miles per hour on seven out of ten days, so that a balloon having a proper speed of 28 miles an hour could maneuver in all directions 81 times in 100, and could progress 5 1-2 miles an hour against the wind at least 71 times in 100. Since the frequency of a wind of about 20 miles per hour at Chalais coincides nearly with that at Blue Hill, as stated in Chapter I, it follows that the speed-qualifications for dirigible balloons operated at low levels are about the same on the two continents. Colonel Renard believed that the conquest of the air would be practically achieved whenever a dirigible balloon could be constructed having a velocity of twenty-eight miles per hour, which it could maintain during ten or twelve hours. We shall see later how nearly these conditions have been fulfilled by perfecting the motors and by diminishing the resistance of the balloon to the air.

The gasoline motor as applied to automobiles had been improving in efficiency and decreasing in weight during the ten years following Renard's experiments, and in 1900 a young Brazilian, Alberto Santos-Dumont, first applied one to a small balloon. After constructing six balloons, in which he did not profit by the experiences of his predecessors, he won a prize of $20,000 offered by M. Deutsch de la Meurthe, by sailing from Saint Cloud around the Eiffel Tower, a distance of three and one-half miles, and returning within half an hour, a feat which was accomplished, after several trials, on October 19, 1901. The envelope of this balloon was 108 feet long and 20 feet in diameter, with a gasoline motor which could develop 18 or 20 horsepower. The speed over the ground in the trial quoted was, according to the figures given, 14 miles per hour, but, on account of the wind, the actual velocity through the air was about 19 miles per hour. While this was somewhat faster than the *France,* it must not be forgotten that the latter, the first successful dirigible balloon, or aëronat, was constructed by Captain Renard six years previously. Santos-Dumont's great service consisted in popularizing the motor-balloon and in inducing the French government to take up the aëronat again. Santos-Dumont constructed no less than 14 balloons of various sizes and in 1904 he came to America with one of them as the only serious competitor for the prize of $100,000 offered by the Louisiana Purchase Exposition. Santos-Dumont had been at St. Louis during the previous year in order to assist a committee, of which the author was a member, to formulate rules to govern the competition. Just before the trials his balloon was mutilated in an unexplained manner within the Exposition grounds, and Santos-Dumont at once returned to Paris. In his many ascensions he suffered serious accidents but always escaped without injury. Other experimenters with dirigible balloons were not so fortunate and two met with fatal accidents. A compatriot of Santos-Dumont, named Severo, and his assistant, were killed by their motor balloon taking fire during its trial over Paris in 1902, and later in the same year De Bradsky and his mechanician were also killed by the car of their aëronat breaking away when above Paris.

The balloon of Santos-Dumont was not suitable for military purposes and that end was attained a few years later by the Lebaudy brothers, rich French sugar-refiners. In 1896 they commissioned an engineer named Julliot to design a dirigible balloon and the first model, called the *Jaune,* from the yellow rubber cloth, made in Germany, which composed the gas-envelope, was completed in 1902. It formed with its car a vertical triangle, the apex pointing downward with the center of gravity above. Julliot endeavored to secure stability when in motion and to avoid the injurious oscillations that Colonel Renard had shown were set up whenever a certain velocity was exceeded and which, in the case of the *Jaune,* was 23 miles per hour. Consequently, planes of incombustible fabric were placed underneath the balloon and were afterwards extended far behind the rudder so as to make the airship a combination of balloon and aëroplane.

To maintain the shape of the gas-bag, which is essential in all non-rigid envelopes driven against the wind, the *ballonet,* proposed more than a century before by General Meusnier, was employed. This is a large pocket of rubber fabric within the gas-bag, which can be filled with air from a motor-driven blower in the car. Valves in both *ballonet* and gas-bag open at pre-determined pressures, and as the balloon rises the pressure of the external air diminishes and the gas tends to expand, thereby compressing the air in the *ballonet,* which escapes by the valve. When the balloon descends the gas contracts and under the increased external pressure both gas-bag and *ballonet* become flabby until the blower replaces the air which had been expelled and thus the rigidity and shape of the balloon are maintained. The *Jaune,* having a length of 183 feet, a diameter of 32 feet, and holding 80,600 cubic feet of hydrogen gas, was propelled by a 40-horse-power Daimler motor, which turned twin-screws, at a maximum speed of 26 miles per hour, this being reduced to an average speed of 14 miles in one hour. In the 29 voyages undertaken, the balloon returned to its starting point 28 times. In 1904 the *Lebaudy,* a larger balloon of the same type was built, and after fulfilling various tests, was accepted by the French War Department. During these trials the balloon, carrying three persons, went from Moissons to Meaux, an air-line distance of 57 miles, in two hours and thirty-five minutes, and from Meaux to Chalons, 61 miles, in three hours and twenty-one minutes. The balloon becoming damaged was sent to the fortress of Toul for repairs, after which it made a series of successful reconnaissances and on its seventy-second ascension carried five persons.

This type of balloon having been adopted by the French government for military purposes, the *Patrie* was brought out in 1906. Its gas-bag was 197 feet long, this being approximately six times its maximum diameter, which occurred about two-fifths of the length from the front. The cigar-shaped form of Renard was retained, but while the *Lebaudy* was pointed at the rear to secure the least resistance, in the *Patrie* horizontal and vertical planes placed there added to the stability and so the stern of the balloon became ellipsoidal. The volume at first was 111,250 cubic feet, but later its volume was increased by 17,660 cubic feet. The *ballonet* had a volume of approximately one-fifth the total contents, in order to permit a height of nearly one mile to be attained (since there the reduction in air-pressure is one-fifth), and to descend, while keeping the gas-bag rigid, the air being pumped into the *ballonet* as the gas was let out. A feature of the *Patrie* was the long suspension of the car, which hung from an elliptical frame of nickel-steel tubes, this in turn being attached by toggles along about 70 feet of the gas-bag. Steel cables, arranged in a triangle, connected the frame with the car, thereby insuring rigidity. For transportation the metal frame could be quickly detached from the bag and the frame taken apart. The boat-shaped car, which is shown in Fig. 20, was of nickel-steel tubing, 16 feet long and 5 feet wide, and could carry seven persons. It terminated below in a point which struck the ground first in landing and so protected the propellers. There were two of these, eight and one-half feet in diameter, placed on

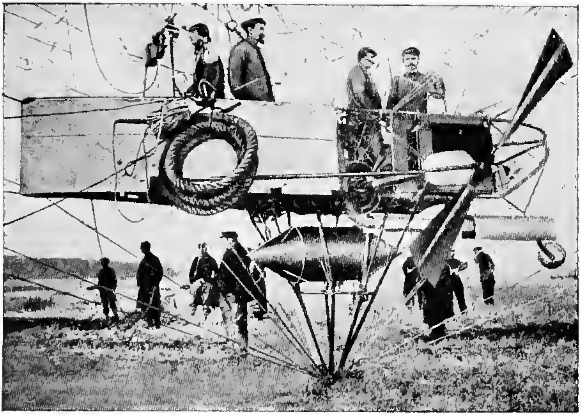

FIG. 20.—Car of the *Patrie*.

either side of the car, and they were revolved 1,000 to 1,200 times a minute by a 70-horse-power Panhard and Levassor four-cylinder motor. The gasoline tank was contained in the pyramidal frame underneath the car. In operation the pilot stood at the front of the car and the engineer at the rear, while the officers had at their disposal a tele-photographic apparatus and a 100-candle-power acetylene searchlight. Besides the fixed horizontal and vertical planes, which enabled the air-ship to maintain a constant level and to move in a straight line without deviating to the right or left, a movable horizontal plane, above the car and near the center of gravity, counteracted the rise and fall of the balloon due to change in volume of the gas, or other causes, and could also produce these motions and so reduce the loss of gas and ballast to a minimum.

The perfected *Patrie* made a number of long trips at an altitude of 2,500 to 3,000 feet and on November 23, 1907, went from Chalais-Meudon to Verdun, a distance of 187 miles, in six hours and forty-five minutes, against a light northeast wind. A few days later an accident to the engine necessitated a landing,

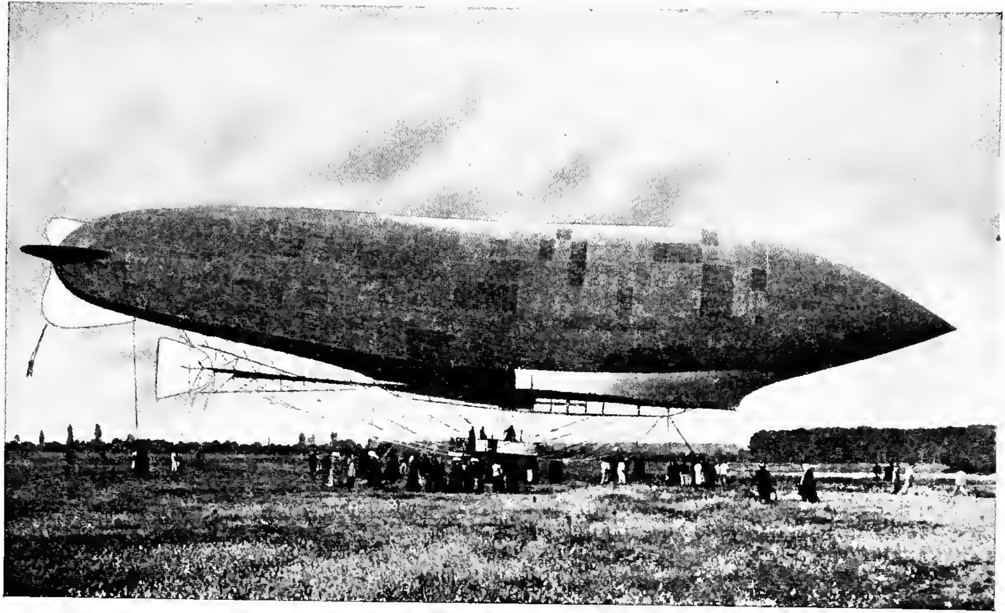

Fig. 21.—Military Dirigible the *République*.

when a gale tore the airship from the company of soldiers who were holding the lines, and it drifted over France and Ireland and out to sea. Another similar balloon called the *République* was at once constructed by Julliot for the French government, differing only from the ill-fated *Patrie* in having 2,000 cubic feet more gas capacity, which gave a total lift of 2,700 pounds for passengers, ballast, fuel, etc. This latest French military dirigible is shown in Fig. 21. When inflated with pure hydrogen it can carry eight men a distance of 500 miles without stops, and the 80-horse-power motor gives it a probable speed of 28 miles an hour. This was about the speed of the *Patrie,* which had, however, with four men a radius of action of only 280 miles.

Another notable airship is the *Ville de Paris,* built at the expense of M. Deutsch de la Meurthe, a patron of aëronautics in France. The first model, which was constructed from designs of the engineer, Tatin, not proving successful, another one was built by Surcouf, the well-known balloon maker, who followed in many respects the ideas of Colonel Renard. After the loss of the *Patrie,* M. Deutsch offered his balloon to the French government, which accepted it. The gas-bag is 200 feet long, with a diameter of 34 1-2 feet, which gives the same ratio as in the *France* and the *Patrie,* the maximum diameter being, as in the last-named balloon, about three-eighths of the distance from the front. The middle section is cylindrical, with conical sections in the front and rear. At the extreme rear is another cylindrical section, around which cluster four little cylinders, each surmounted by a still smaller one and all connected with the main reservoir. These cylinders replace the horizontal and vertical planes of the *Patrie,* which maintained stability, but offer more resistance to the air. Motion up or down is obtained by two pairs of horizontal planes, as in the *Patrie.* The deformation of the gas-bag, which was noticeable in that balloon, is avoided by distributing the weight along nearly the entire length of the envelope. The car is a wooden trestle with aluminum joints and wire braces. A 70-horse-power "Argus" engine drives a two-bladed wooden propeller, placed in front of the car, where it works in undisturbed air as in the *France.* It turns only 250 times a minute, on account of its large diameter of 20 feet and pitch of 26 feet, and the proper speed of this balloon probably does not exceed 25 miles per hour.

The *Clément-Bayard,* similar in design to the *Ville de Paris,* has been constructed by the Astra Society, and sold to the Russian government for $40,000. It has a slightly

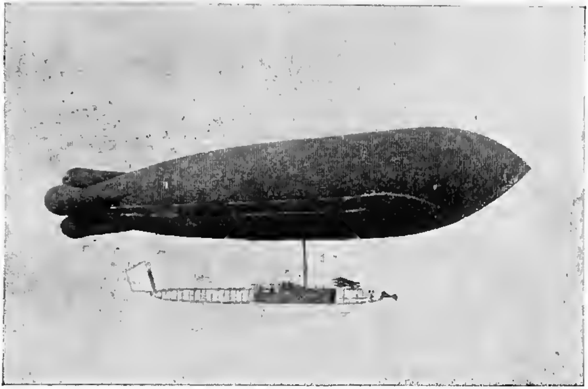

FIG. 22.—Dirigible. *Clément-Bayard.*

greater cubic contents than the *Ville de Paris,* and is distinguished from it by the rear gas-bags, which give stability, being conical and therefore presenting less resistance to motion. The car, built of steel tubing, is inclosed in aluminum plates, and can accommodate eight persons. A Clément-Bayard motor of 100 horse-power drives a wooden screw, 16 feet in diameter, at 380 revolutions a minute, the screw being placed in front of the car. This balloon, shown in Fig. 22, may be regarded as the most perfect French type, and probably attains 30 miles per hour. In fact, a round trip from its shed at Sartrouville, over a distance of 125 miles, was made at a speed of 27 miles per hour. A condition of its acceptance by the Russian government was that it should ascend to a height of seven-eighths of a mile by its own power.

Two other French dirigibles may be mentioned, namely, the *Malécot,* which is a combination of balloon and aëroplane, and the small portable balloon made by the Zodiac Company, holding 25,000 cubic feet, which, when filled with hydrogen gas, will lift two persons, or with illuminating gas, one person, and which its engine of 16 horse-power can propel at the rate of about 13 miles per hour. The various parts are detachable from each other, so that they may be easily packed for transportation by wagon or train. The cost of this balloon is only $5,000.

We will now proceed to Germany, where we saw, in the last chapter, twenty years ago applications of the free and captive balloon to scientific and military purposes. The first German dirigibles were not successful. Dr. Wölfert's motor-balloon, while being tried at Berlin in 1897 was set on fire by the gasoline-motor and both Wölfert and his mechanic perished. In the same year an aluminum balloon, whose construction was begun several years before by an Austrian engineer named Schwarz, met with disaster at Berlin. The idea of using a metal gas-receptacle was proposed by a Frenchman, Marey-Monge, in 1842, and the project was revived when aluminum could be provided cheaply. Count von Zeppelin, a former general in the German army and adjutant to the King of Wurtemburg, conceived the idea of constructing a large and rigid airship, which should preserve its shape under all conditions. This idea was not favorably received by the Prussian Ministry of War, and Count von Zeppelin accordingly organized a company to build the largest of all airships. A site was given by the King of Wurtemburg at Manzell, near Friedrichshafen, on the shore of Lake Constance, and in 1898 a great floating shed was anchored at its front end, which, accordingly thus always faced the wind. In the shed a strong aluminium frame, having 16 sides, but of general cylindrical appearance, 420 feet long and 39 feet in diameter, with bomb-shaped ends, was put together. The interior was divided into 17 compartments, each holding an ordinary balloon, which had a combined volume of 390,000 cubic feet. The metal frame was covered with rubber cloth coated with pegamoid and this skin not only furnished a smooth surface and protected the gas-bags against damage and the influence of weather, but the insulating air-space decreased the changes of temperature, which cause a rise or fall of the balloon according as the gas is expanded or contracted. Thirty-three feet below the frame were hung two aluminium boats, each provided with a 16-horse-power Daimler benzine motor. The scheme of duplicate motors, to prevent stoppage through accident to one of them, originated with Count von Zeppelin and was adopted by other constructors. The four-bladed air propellers, with a diameter of only about four feet and rotating 1,000 times a minute, were placed right and left of the motors, near the center of pressure and somewhat below the longitudinal axis of the balloon. Vertical and horizontal planes served to maneuver sidewise and up or down, but to regulate the equilibrium and to raise and lower the prow there was a heavy counterweight, which could be shifted on a horizontal truss under the balloon. The surface of the lake furnished a level surface for launching this long rigid structure, while the floating shed afforded shelter. The filling of the 17 balloons required 2,600 cylinders of compressed hydrogen gas and the preliminary trials were not commenced until July, 1900. A series of accidents prevented them from being successful, but in October a speed of 19 miles an hour was obtained, the greatest hitherto attained by any motor-balloon, and when it is remembered that this airship equaled in size many ocean steamships and exceeded most of them in speed, although possessing engines of only 32-horse-power, the result must appear extraordinary. It will be noticed that some of the ideas which have been used to secure safety at sea, namely, the division into compartments and the duplication of the engines, were applied to this balloon. The great size of the *Zeppelin*, provided it can be controlled, is an important factor in its success, for, as Mr. Chanute predicted several years ago, since the cubic contents and lift increase with the cube of the dimensions and the weight in a far smaller ratio, a balloon of this size should be able to lift a very powerful motor and attain a speed of thirty or more miles an hour, which, as we shall see, has recently been done. Having spent a large personal fortune on his experiments, Count von Zeppelin in 1903 sought unsuccessfully, through the writer, to have another airship constructed by the St. Louis Exposition which had advertised aëronautics as a feature.

Five years elapsed before the Count was able to secure the means to build a second airship, improved in almost all respects, but especially by an increase of the motive power to 170-horse-power and enlarged propellers. In front and behind three vertical planes helped to steer in a horizontal direction, and between them and the car horizontal planes facilitated changes in a vertical sense, the steering being effected from the front car.

The trial flights in the winter of 1905-6 were executed under adverse conditions, and after a landing the airship was damaged by a

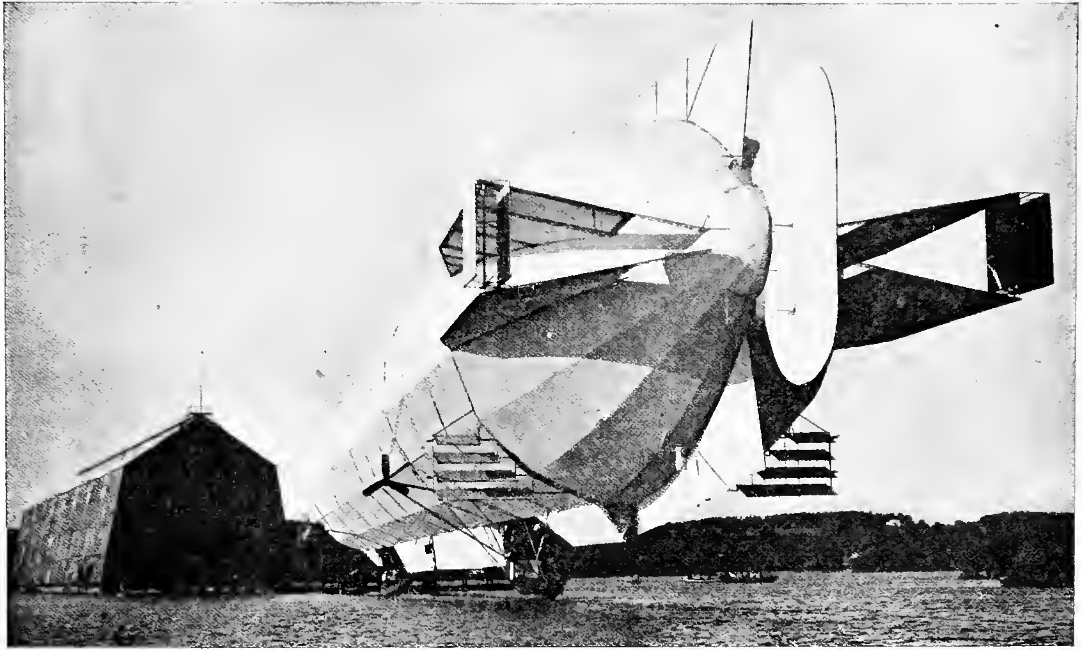

FIG. 23.—*Zeppelin IV*. on Lake Constance.

gale. Undaunted by his new misfortune, Count von Zeppelin built No. III, having the same length as the last, but more powerful motors, and possessing a carrying capacity of eight persons and 5,500 pounds of ballast, etc. The tests in October, 1906, were entirely successful, for according to the official report to the Minister of War, the airship was extremely stable and easily turned, while its speed (namely, 30 miles per hour) was greater than that of other airships. A height of half a mile was reached, and eleven persons were carried 67 miles in two hours and seventeen minutes, which considerably surpassed the performance of the French military balloon. The German government now lent financial aid to enable the advantage of the rigid system of construction to be demonstrated. A new floating shed was erected and in it another airship was constructed, which was successfully tried in the autumn of 1907 and made one continuous run of eight hours. Modifications suggested by experience were introduced in Model IV, of which photographs are given in Figs. 23 and 24. This balloon had a length of 446 feet, with a maximum diameter of 42 1-2 feet, and its 16 compartments could contain 460,000 cubic feet of gas, which gave a total gross lift of 16 tons. Each boat-like car was provided with a 110-horse-power Daimler motor that drove a pair of three-bladed propellers about 15 feet in diameter. A third car for passengers only was built into the keel under the center of the framework. The balloon is towed from its shed, while resting on its floating cars, and ordinarily descends again on the lake as seen in Fig. 23. The steering apparatus at the stern was considerably enlarged and, with the steadying planes at the sides, are shown in the picture. A huge vertical rudder was attached to the extreme end of the rigid frame and an additional rudder placed between each set of horizontal planes on the sides. For vertical steering there were four sets of movable horizontal planes, working like a shutter, near the extremities of the frame and at about the height of the propellers. Early in the summer of 1908 this balloon made a series of voyages, and in a notable one on July 4, crossed the mountains to Lucerne and Zurich and returned over Lake Constance. The start on this tour is represented in Fig. 24. The closed circuit,

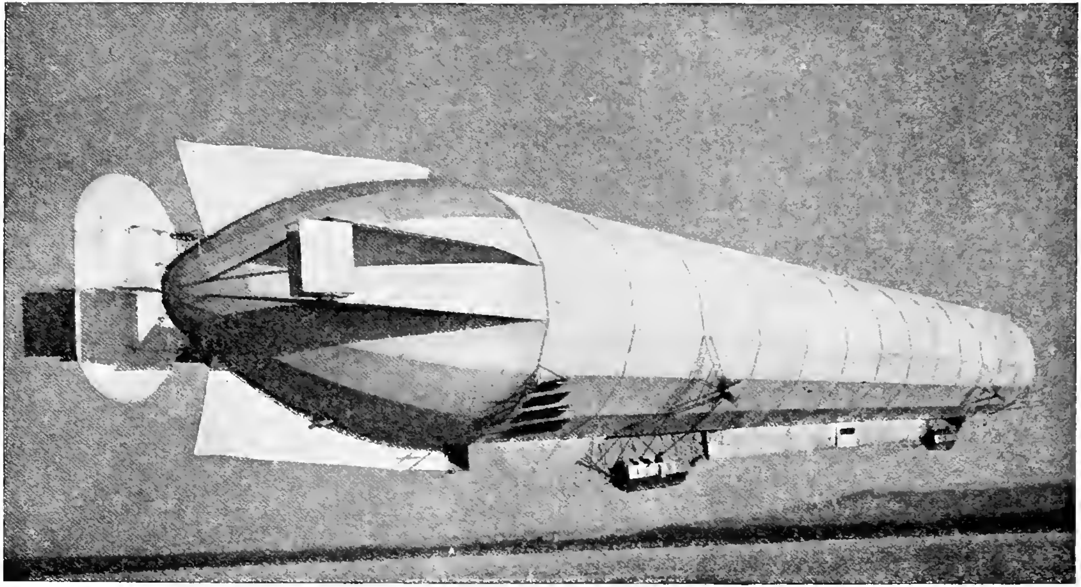

FIG. 24.—*Zeppelin IV.* in the Air.

shown in Fig. 25, measured 235 miles and was accomplished in twelve hours, giving 20 miles an hour as the average speed of the balloon. On August 4, quite unexpectedly, the great 24-hour voyage required for the acceptance of the balloon by the government, was undertaken. It was intended to follow the Rhine to Mainz and return in a straight line to Friedrichshafen. Two land-

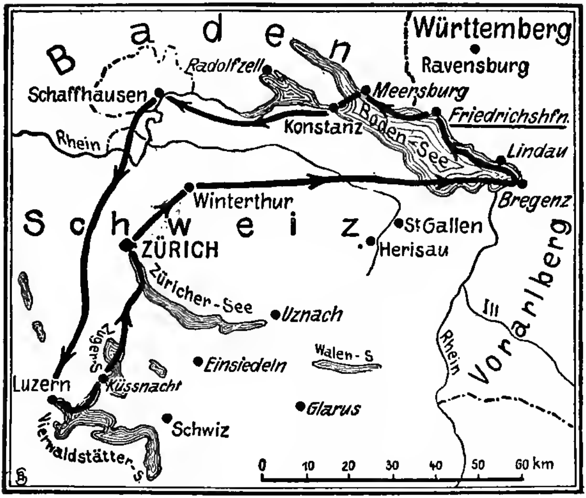

FIG. 25.—Voyage of *Zeppelin IV*.

ings for repairs were made, and during the second one, in the vicinity of Stuttgart, a squall tore the airship from its moorings and carried it into the air where it was set on fire, probably by an electrical discharge, and in a few minutes was completely destroyed. Thus within a year, through similar accidents, both France and Germany lost their best military airships.

The accident had no bearing on the merits of the rigid system of construction as exemplified in the *Zeppelin,* which showed stability and dirigibility in both a vertical and horizontal direction and the possibility of landing on dry land. At its last landing the balloon had been in the air 20 hours and 45 minutes and had traveled 378 miles.

The enthusiasm of the German people, which had been aroused by the voyages of the monster airship, manifested itself after its destruction in an outburst of patriotism, and the subscriptions which were opened in all parts of Germany to aid Count von Zeppelin, soon amounted to $1,500,000. This was paid to a Zeppelin Society which has acquired a great plant at Friedrichshafen in order to build airships on a large scale. The reconstructed

Zeppelin III. was bought by the German government and, manned by officers of the Balloon Battalion, recently made the voyage to Dingolfing, 172 miles, and after landing there and at Munich in a strong wind, returned safely to Friedrichshafen. It will now be stationed at the fortress of Metz.

Two other German military balloons deserving description are the *Gross* and the *Parseval,* the former being the property of the German War Department and the latter owned by the Society for the Study of Motor Balloons. The first *Gross* airship was built in 1907 from designs of Major Gross, commander of the Balloon Battalion at Tegel, near Berlin. It resembled in many respects the *Patrie* but was smaller, having a volume of but 63,000 cubic feet and a motor of only 20-24 horse-power. In 1908 another model of 176,000 cubic feet capacity was constructed on the same lines, and driven by two Daimler motors, attained a speed of 27 miles per hour. On September 11, 1908, this balloon, carrying four passengers, made a round trip from Berlin of 176 miles in a little more than 13 hours, which is one of the best trips in regard to distance and speed yet made by an airship returning to the starting-point. Unprejudiced experts consider this semi-rigid type to be the most promising military balloon.

The *Parseval* was designed by Major von Parseval, formerly of the Bavarian army, who embodied in the gas-bag the principle of his kite-balloon. Several models have been constructed by Riedinger of Augsburg and the last is being tried by the German government. The envelope, holding 113,000 cubic feet of gas, is cylindrical, rounded in front and pointed at the rear, and contains two *ballonets* at either end which by their pressure on the gas maintain the envelope rigid and also serve to change the height. In order to rise, the rear one is filled with air, so that the front end is inclined upward and a forward motion through the air tends to raise the balloon, while to descend the reverse process is followed. In this way the altitude can be regulated within 600 feet with positive and negative variations of 1,000 feet around the zone of equilibrium. For greater changes in height ballast must be used. At the rear are two lateral "stabilizators" and under the envelope is a keel, to which are attached the vertical rudders. The car is hung on trolleys from two steel cables

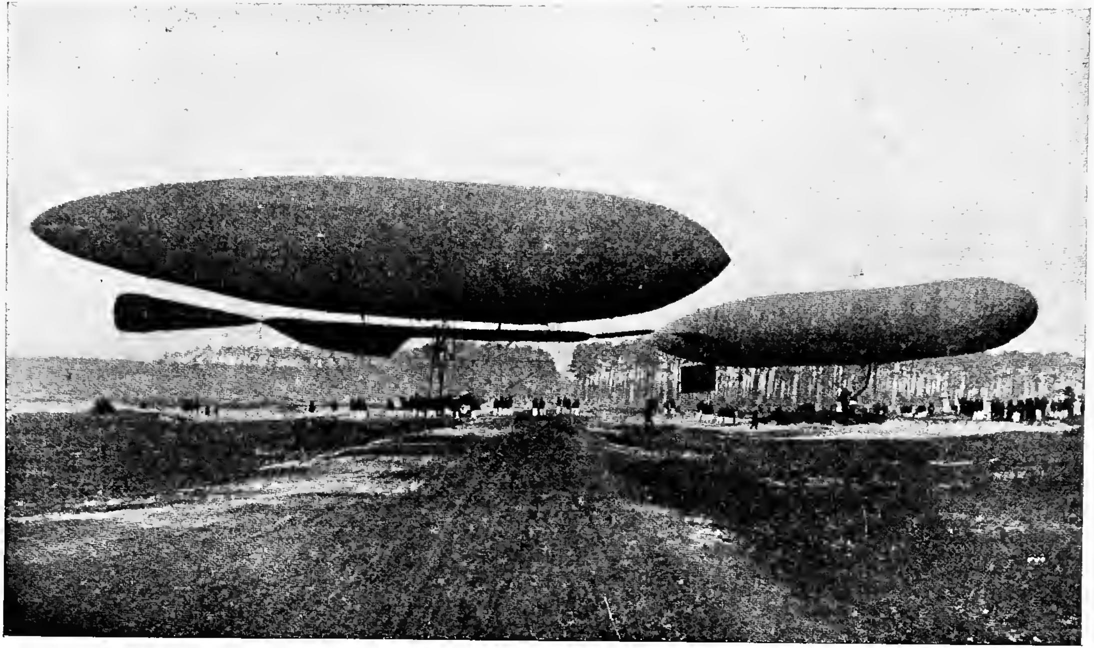

FIG. 26.—*Gross II.* and *Parseval II.* at Tegel.

and moves forward under the impulse of the propeller so that it balances automatically. The propeller, driven by an 85 horse-power Daimler-Mercedes motor, is also peculiar in having four cloth blades which only become rigid under the influence of centrifugal force when turning. An advantage of the *Parseval* is the possibility of packing for transportation in two wagons, since the rigid parts are few and small, and it can be easily set up and filled on the field when required for military purposes. Fig. 26 shows the two rival airships, *Gross II.* (on the left) and *Parseval II.* (right) which are housed side by side at Tegel. A trial of them on September 11, 1908, showed their defects under stress of weather. Both were summoned by the German Emperor to Potsdam, but the *Gross,* unable to face the strong wind, was forced to return home, while the *Parseval* met with an accident and fell to the ground.

Dirigible balloons, constructed in England, Russia, and Italy, are inferior to those just described, but in the United States an airship has been acquired by the Signal Corps, which, while not comparable with the European balloons, either in size or speed, presents the advantage of simplicity and cheapness. It is shown in flight in Fig. 27 and was constructed in 1908 by T. S. Baldwin in competition for a dirigible balloon, which, without exceeding 120 feet in length, should have a speed of 20 miles an hour. The gas envelope is spindle-shaped, 96 feet long with an extreme diameter of 19 1-2 feet and a capacity of 20,000 cubic feet, including the *ballonet.* The material is two layers of Japanese silk with vulcanized rubber between them. The motor is a 20-horse-power water-cooled Curtiss motor, which drives a propeller at the front of the car. A fixed vertical surface at the rear checks rolling, and a horizontal surface on the vertical rudder diminishes pitching. This is also counteracted by double horizontal surfaces, like a Hargrave kite, which can be moved obliquely by a lever in order to control the vertical motion, a device first employed in the *Ville de Paris.* The total lifting power of the Baldwin balloon is 1,350 pounds, of which 500 pounds are available for passengers, ballast, fuel, etc. A speed of over 19 miles per hour was obtained, and 70 per cent. of the maximum speed was maintained during an endurance run of two hours.

FIG. 27.—Signal Corps Dirigible No. 1.

The various dirigible balloons described may now be classified into three principal types: the rigid, of which the *Zeppelin* is the most conspicuous example; the semi-rigid, like the *Gross* and the *République;* and the non-rigid, of which the *Parseval* is the most perfect exponent. The rigid construction has the advantage of strength and durability, but a great weight must be lifted (in the *Zeppelin* the metallic frame weighs 17,000 pounds) and the airship is not transportable except on the water or in the air under its own power. The cost, also, is great, the *Zeppelin* costing more than one hundred thousand dollars. In the semi-rigid system the gas-bag is pliable but has beneath it a metallic sole which is intended to prevent deformation of the envelope and serves to attach the car. In the non-rigid system (first applied in the *France*) there is no union of cloth and metal, the pliable envelope being entirely independent of the car containing the motors, etc., and connected with it by flexible cords. This type of airships is easily transportable. In all the maintenance of form is a *sine qua non,* and in balloons other than of the *Zeppelin* type is assured by the *ballonet à air.* The improvement in light motors since 1885 is shown by the fact that, whereas the electric-motor with storage battery used in the *France* weighed 100 pounds per horse-power, present explosive motors weigh less than 10 pounds per horse-power, exclusive of the fuel. While the dirigibility of a balloon depends on the power of its motor, its speed cannot be increased beyond 17 to 25 miles per hour without causing its prow to rise and the balloon to overturn, unless special precautions are taken. Consequently the length of the gas-bag may not exceed five or six times its diameter and must be provided with projections behind, as far distant as possible from its center of gravity, which like the feathers on an arrow, tend to control its direction. Besides stability *en route,* the facility of vertical motion must be afforded by movable planes nearly parallel to the principal axis of the balloon. A dirigible balloon is but little lighter than the air which it displaces, consequently its rise and fall is effected chiefly by dynamic rather than by static action and without the loss of much ballast or gas. The motive power increases as the cube of the speed for balloons of similar design, and the weight per horse-power diminishes in the same ratio. Taking, for example, a balloon 33 feet in diameter, to give it a velocity of 13 1-2 miles per hour requires the expenditure of 8.64 horse-power, and supposing the motor to absorb one-fifth of the ascensional force, the permissible weight per horse-power is 1.78 pounds. If we double the speed, that is propel the balloon 27 miles per hour, 69 horse-power will be required, and the weight per horse-power can be but 0.22 pound. To gain another 4 1-2 miles per hour requires an addition of 40 horse-power, and 4 1-2 miles more, making the speed 36 miles per hour, would necessitate engines of 163 horse-power, while the weight which can be allowed per horse-power is reduced to 0.09 pound. These computations, by Major Paul Renard, show how difficult it is to gain a few miles per hour at high speeds and how rapidly the allowable weight per horse-power decreases. Since the lift of a balloon increases as the cube of its linear dimensions, but the surface, and consequently the resistance of the air, only as the square of these dimensions, it follows that the larger balloon with an equal speed will carry more weight, exclusive of the motors, than the smaller one.

The dirigible balloon has its prototype in Nature in the fish which, though specifically lighter than the medium in which it is immersed, can rise or fall by expanding or contracting its swimming-bladder, represented by the *ballonet* of the aëronaut. Indeed, in the French balloon the form of the gas-bag resembles the body of a fast-swimming fish.

At the present time dirigible balloons can no longer be considered as useful only on selected days but rather as capable of performing service three-quarters of the time. Thus they can fulfill important functions until they are supplanted by heavier-than-air machines, for it is probable that the conquest of the air will be completed by apparatus of this type. How man first learned to fly, and the progress which he is making in this new accomplishment, will be described in the next chapter.

CHAPTER IV

THE FLYING-MACHINE

MAN has always wished to imitate the flight of birds, that he might leave the ground to which he seemed to be confined, and rise freely into the air. In the Middle Ages there were chronicled various attempts of men to fly, but not until the invention of the balloon was man able to ascend into the air, and even then for a hundred years we have seen that he was unable to direct the course of the balloon, but drifted helplessly with the wind. The balloon has no counterpart in Nature, for there is not a creature that rises in the air because it is lighter, but only by virtue of its own force overcoming gravity, and as soon as this ceases to act, gravity again brings it to earth.

The problem of dynamic flight is indeed a very difficult one, and it is only solved by Nature on a small scale. All flying animals are, in fact, of small size, and hardly exceed twenty-five pounds in weight. Such great birds as the ostrich have been called two-legged giraffes, whose wings were never intended to sustain them in the air, and even among the extinct species of geologic times the skeleton of but one large flying creature has been unearthed, namely the pterodactyl, measuring 20 feet between wing-tips. A quadruped on the ground, a fish floating in the water, or a balloon in the air are sustained without any work being done, so that their dimensions are of small importance. Birds, however, must exert energy simply to sustain themselves in the air. Now, large flying creatures, or machines, have a great disadvantage over smaller ones, for while the wings or surfaces which support them increase as the square of their linear dimensions, the weight increases as their cube, that is, if we double the supporting surface the weight will be quadrupled. This disadvantageous disproportion in the case of large flying animals is shown by comparing the butterfly with the Australian crane, in which the weight per unit of wing-surface is increased one-hundred fold. Therefore, the difficulty of sustentation, that is to say the work necessary, increases with the dimensions of the body and at a certain point becomes so great that its accomplishment is impossible by simple muscular effort, and it is on this account that Nature has not made flying animals of great size.

For the same reason man cannot hope to fly by his own muscular force and must have recourse to powerful motors. Aviation, therefore, could only be realized when the motors had been so improved as to give much energy with a small weight. There is another disadvantage in enlarging the wings or supporting surfaces, inasmuch as to secure equal strength the size of the parts and therefore the weight must be increased in a larger proportion than the linear dimensions, and finally the weight of the wings will become so great that they can barely sustain themselves, and leave nothing for the body, mechanism, and passengers. As regards progression through the air, since the power must be increased as the cube of the speed, the flying-machine has an enormous advantage over the dirigible balloon in requiring much less power to advance through the air, on account of its smaller bulk. But it must be remembered that while the balloon floats, the flying-machine, being heavier than air, must expend force to maintain both lift and speed, although with the aëroplane, as the speed increases the sustaining surface can be diminished, or the load can be increased. The measure of this work is that required to impart to the apparatus a definite speed, and this velocity is the greater as the weight per unit is the larger. It can be shown that flight by downward strokes is impossible unless the weight per horse-power is less than two pounds. As this is not yet possible, we must give the surface what Colonel Renard called " sustaining quality," of which the fundamental principle consists in attacking the air obliquely instead of vertically.

Practically, flying-machines, or aëronefs, may be classified into three distinct types—aëroplanes, helicopters, and ornithopters. Aëroplanes have sustaining surfaces slightly inclined to the horizon and largely outspread in a transverse direction. These surfaces, usually concave below to increase the lift, are fixed with respect to the apparatus and in order to receive the current of air required for support, there is a propeller, generally a screw, driven by a powerful motor. This screw does not sustain the apparatus directly, but advances it horizontally and produces on the sustaining surfaces a current of air which impinges on the lower surface and uplifts it. Therefore, an aëroplane may be considered as a kite in which instead of the wind coming to the kite, the aëroplane itself produces the wind which sustains it by its own motion through the air. Since the propelling mechanism and the sustaining portion are entirely distinct, and support is only possible when it is moving forward, if the screw stops the apparatus descends, but this should be down a gentle slope so that the consequences need not be serious. Aëroplanes have the inconvenience of requiring a large space for starting and landing, which is also true of large birds like the condor. The resistance of the air increases very fast with the speed. For example, let us suppose that for a velocity of 12 miles an hour the resistance of the air diminishes by 230 pounds the weight of the aëroplane; for double the speed, or 24 miles an hour, the pressure which the air will exert on the bottom of the aëroplane is not double but quadruple, that is 920 pounds. If the speed continues to increase, long before it has again doubled, the apparatus will rise from the ground and will continue to fly as long as the speed remains sufficient.

In the helicopter the support is obtained by screws with vertical axes, and is independent of the forward motion, which is a considerable advantage. To effect motion in a horizontal direction, another screw is required, or the axis of the supporting screw is inclined to the vertical so that in rising it also advances in a given direction. The helicopter has an advantage over the aëroplane in requiring only a small space for starting and landing, but is wasteful of motive power because its sustaining power is very much inferior to that of the aëroplane. This results from the vertical screw setting the mass of air in motion so that its action is not so efficient as when it comes into new masses of air, like those encountered by the aëroplane propeller.

In the aëroplanes now used the resistance to their motion forward varies between 1-8 and 1-5 of the weight, requiring the screw to exert that much propulsion. In a helicopter the lifting force must equal the total weight of the apparatus, which must be propelled forward besides. Therefore, while it is improbable that helicopters will ever supplant aëroplanes, it appears possible to combine the two systems so as to act like a helicopter at the beginning and end of the voyage, in order to facilitate the maneuver in a limited space, and during the voyage to have the aëroplane operate in an economical manner.

The ornithopter, as the name implies, imitates the flapping wings of a bird. Only small machines have as yet been constructed, and it is probable that they will always remain toys. The secret of bird-flight, long believed to be an insoluble mystery, is now explained on the supposition that birds are aëroplanes whose extended wings, apparently stationary, act as sustaining surfaces, especially near the body, while only the extremities serve to propel the bird. A bird's wing is thus an organ with multiple functions, serving generally as a sustaining plane and propelling force, and occasionally as a sustaining screw. It does not seem probable that man will ever construct ornithopters of large size. As man has abandoned legs and fins for mechanical locomotion on land and water, so in aviation there is no use to imitate beating wings, the movement of rotation being characteristic of machines.

In 1886 Colonel Renard predicted that

whenever the weight of the motor was reduced below 11 pounds per horse-power an aëroplane could fly, and with a motor weighing about four pounds a helicopter would rise, and both these prophecies have now been fulfilled. It has been remarked by Major Paul Renard, to whom we are indebted for some of the preceding analysis, that perhaps never in the history of invention has there been one which required such perseverance as mechanical flight. Most of the inventions which we make use of to-day, such as railroads, steamboats, telegraphy, and photography, are of recent date and were not thought of 200 years ago. The secret of aviation, however, has defied all efforts for a much longer period, because man has not merely dreamed of the conquest of the air but also attempted to realize it with inadequate motors. The partial solution by aërostation did not stop the pursuit of aviation, and since the end of the eighteenth century patient investigators everywhere have been seeking to achieve dynamic locomotion in the air. And now, at last, its off-denied possibility has been demonstrated.

Let us examine the more important attempts which have led to the accomplishment of mechanical flight. In the first place, we can point with pride to the fact that, whereas the balloon is certainly of French origin, the problem of human flight, by a machine heavier than air, was solved in America, and the names of Langley, Chanute, and Wright will always be honored as having successfully promoted the navigation of the air by machines heavier than itself.

In considering the lines of investigation, we may divide them into two categories; first, the trials of models, or full-sized machines provided with motors, and second, the experiments with soaring or gliding surfaces to which motor power was applied only after stability was obtained. While this last and more recent method is the one which led to success, we will first consider the earlier experiments made with motor-machines.

The first aëroplane which had any chance of success was designed by Henson, in England, in 1843. This so-called "aërial steam carriage," which does not appear to have been constructed, had wings that measured 140 feet across, and although the proposed steam engine which drove the propellers weighed too much to permit the apparatus to leave the ground, yet

Henson's project may be regarded as the precursor of the flying-machine of to-day.

During the latter half of the nineteenth century many experiments with power flying-models, driven by twisted rubber, compressed air and steam, were made by Pénaud, Tatin, Hargrave, Phillips, Langley, and Richet. The most successful experiment was that of the late Professor Langley, secretary of the Smithsonian Institution, whose *Aërodrome,* weighing 27 pounds, and driven by a one-horse-power steam engine, in 1896 made three flights of about three-fourths of a mile each, over the Potomac River, near Washington, the apparatus alighting safely each time, and being in condition to be flown again. This, the first flying-machine to be propeled a long distance by its own power, is shown in flight in Fig. 28. Quoting from Mr. Chanute, the eminent engineer of Chicago, whose own experiments and writings have been of the greatest service to aviation, the striking fact which appears from all these model experiments is, that it requires a relatively enormous power to obtain support in the air. Taking the best data, the weights sustained were but 30 to 35 pounds to the horse-power expended, thus comparing most unfavorably with the weights transported by land or by water; for a locomotive can haul about 4,000 pounds to the horse-power upon a level track, and a steamer can propel a displacement of 4,000 pounds per horse-power on the water at a speed of 14 miles per hour.

Professor Langley, in his epoch-making work *Experiments in Aërodynamics,* published in 1891, made this prediction: "The mechanical suspension of heavy bodies in the air, combined with very great speeds, is not only possible, but within reach of mechanical means which we actually possess." After the successful flight of his model in 1896, Professor Langley wrote: "I have brought to a close the portion of the work which seemed to be especially 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."

After experimenting with models which are often unsuitable for reproduction on a large scale, four famous inventors, Maxim, Ader, Kress, and Langley, each constructed a machine to carry a man, and all were unsuccessful because they lacked stability and strength. In 1894, Sir Hiram Maxim built in England a flying-machine to carry three men, which has never been equaled in size. It consisted of superposed aëroplanes of 4,000 square feet surface with two screws driven by a 360-horse-power engine of novel design. The machine ran on a track and was prevented from rising far by a rail above. At a speed of 36 miles per hour all the weight of 8,000 pounds was sustained in the air, but in the final test the machine, which is said to have cost $100,000, left the track, and was wrecked.

In 1897, C. E. Ader, a French mechanical engineer, with a grant of $100,000 from the French War Department built his third machine (to which he gave the name of *Avion*), whose form was that of a great bird, with 270 square feet of surface and a weight of 1,100 pounds. Twin screws were turned by a 40-horse-power steam engine which weighed only 7 pounds per horse-power. This machine is said to have flown more than 500 feet in a test at Sartory before a military commission, but its defective balance causing an accident, further aid was refused, and the machine was abandoned.

In 1901, W. Kress of Vienna tested an apparatus with tandem surfaces of 1,011 square feet, the model of which gave good results, but which failed with an inadequate motor.

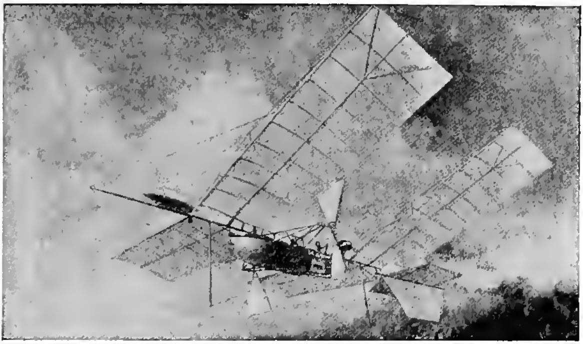

Fig. 28.—Langley *Aërodrome* in Flight.

After the successful flight of the *Aërodrome* Professor Langley obtained a grant of $50,000 from the United States War Department to construct a flying-machine capable of carrying a man. The machine was essentially an enlargement of the model, and with C. M. Manly on board it was twice launched from a house-boat on the Potomac in 1903. In both cases, however, the apparatus, caught in the launching-ways, was precipitated into the river, and Professor Langley, discouraged by the ridicule of the press and deprived of additional funds, abandoned further experiments. That the machine would probably have flown had it been properly launched, was shown five years later by Blériot, in France, who, with a similar type of apparatus, made many flights, starting from the ground.

The failures described indicate as the first requisite that the machine shall be stable in the air, and the equilibrium under the control of its operator. The proper design of the aëroplane, and the requisite skill in managing it before applying a motor, are assured by the other school of experiments founded by Lilienthal.

Otto Lilienthal, a German engineer, built between 1891 and 1896 a number of aëroplanes, with which, using gravity as a motive power and starting from a hill-top he practiced gliding-flight and thus traversed a distance of 400 yards through the air. His last glider with superposed surfaces is shown in Fig. 29. Lilienthal also proposed to apply a motor to his glider, but after making more than 2,000 flights he was killed in 1896 by the machine upsetting in a gust of wind, and three years later the same fate befell Mr. Pilcher, an English engineer, who was using a modified glider. Both these operators shifted their weight so that the center of gravity fell on the same vertical line as the center of pressure, which oscillated through changes in the wind.

Fig. 29.—Lilienthal Glider Descending.

Lilienthal had no imitators in Germany, but, in 1896, Octave Chanute in America began to experiment with man-carrying gliding-machines, in which he reversed the method of Lilienthal to restore balance and caused the surfaces themselves to alter their position, so as to bring the center of pressure back vertically over the center of gravity. Several forms were tried, including a multiple-wing machine, with which the angle of descent was about 10 degrees to the horizon. In this, five pairs of wings were pivoted upon each side of a truss permitting them to be pushed back or drawn forward as the wind increased or decreased. Another glider had two superposed surfaces and a tail or rudder for equilibrium. This gave an angle of descent as small as 8 degrees, with a velocity of 17 miles an hour, and nearly 1,000 glides were made without accident to the operator. Messrs. Herring and Avery collaborated with Mr. Chanute in these experiments.

In 1900 Wilbur and Orville Wright, bicycle-makers of Dayton, Ohio, got into communication with Chanute and undertook experiments based on a radically different principle. Instead of automatic equilibrium, obtained by surfaces making a dihedral angle with one another, the machine was arranged so that it would not tend to right itself but be as inert as possible to the effects of change of direction or speed, in order to reduce the effect of gusts of wind to a minimum. The fore-and-aft stability was secured by giving the aëroplane a peculiar shape and the lateral balance by arching the surface from tip to tip, or just the reverse of what had been done by some preceding experiments. Thus by contrivances actuated by the operator the balance could be regulated. Practically this was done by an adjustable rudder in front and warping the tips of the wings. The operator lay horizontally to diminish the resistance of his body, and in landing a pair of runners slid on the ground and checked the momentum.

A thousand glides were made from a sandy hill on the North Carolina coast during the next three years, without accident, the aëroplane sometimes hovering in the air for a minute or more, and covering distances up to 600 feet, the angle of descent having been reduced to 5 or 6 degrees (Fig. 30). As a relative wind of about 20 miles an hour was necessary to support the glider the experiments were generally made with a wind of from 9 to 28 miles per hour, blowing up the hill.

The Wrights were now in a position to build a successful power-flyer and accordingly they applied to the glider a 16-horse-power motor driving double screws behind, bringing the total weight of the apparatus up to 750 pounds. On December 17, 1903, it was tried on the Kill-Devil dunes, North Carolina, against a wind of 22 miles an hour. After running on a rail for a distance of 40 feet the machine rose into the air to a height of 10

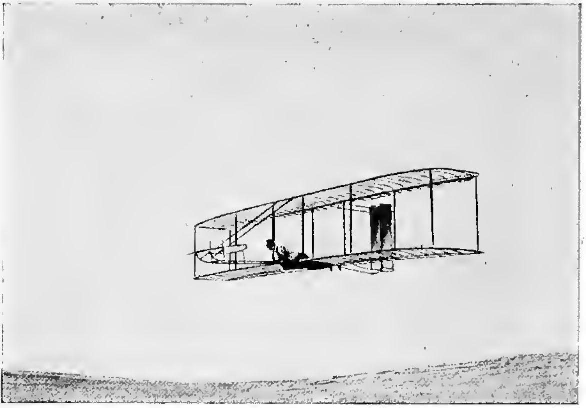

FIG. 30.—Wright Glider Descending.

feet, advanced with an actual speed of 10 miles an hour over the ground, and 30 or 35 miles through the air. The first trial lasted only twelve seconds, but succeeding trials increased in length until in the last the machine remained in the air fifty-nine seconds, and covered a distance of 852 feet. These, then, were the first considerable flights in a motor-driven flying machine carrying a man. The experiments were transferred to a field in the environs of Dayton in the spring of 1904, but it was not until the autumn that flights were made in a circle. Finally on October 5, 1905, a distance of 24 miles was traversed in thirty-eight minutes.

At this time the Wrights, failing to interest the United States government, offered through Captain Ferber of Paris to sell to the French the machine, guaranteed to fly 30 miles an hour, for the sum of $200,000. Although the experiments of the Wrights had been reported in France, their claims were not generally believed, and the offer to sell the machine was not accepted. Public interest, however, was aroused. Captain Ferber had already experimented with a glider of the Chanute type, and had studied the question of applying a motor. Mr. Archdeacon had done the same with aëroplanes dragged over the water, but the first aviator who rose by self-contained power, before a board of control, was A. Santos-Dumont. He used a cellular aëroplane, resembling a Hargrave kite, with a box-like rudder in front, and driven by an aluminum screw connected to a 40-50 horse-power explosive engine. As there was no tail in the rear of the wings, this machine had the appearance of a flying duck, with the neck stretched out in front. Two bicycle wheels allowed the aëroplane to run on the ground until the velocity was sufficient to raise it by the action of the air under the wings. On September 13, 1906, Santos-Dumont rose from the ground with a velocity of 23 miles an hour, and progressed 30 feet through the air, thereby proving to those persons who ignored the flights of Ader and the Wrights, that mechanical flight was possible. On November 12, 1906, Santos-Dumont made a flight of more than 700 feet and won several prizes offered by the French Aëro-Club.

Other French experimenters, such as Esnault-Pelterie, Blériot and de la Vaulx, tried monoplanes during the next two years, with more or less success, but Farman and Delagrange achieved the most brilliant results with biplanes constructed by Voisin brothers, specialists in aviation apparatus. Delagrange, a French sculptor, first demonstrated the biplane in Europe on March 30, 1907, and since then each of these two aviators in their flights have successively broken the records of the other. Farman, who on October 26, 1907, attained a distance of half a mile in a straight line, was soon able to describe circles, and on February 11, 1908, made the first complete circuit of about a mile in one minute and a half. In the summer of 1908 Farman came to America and exhibited his machine in New York. Returning to France he carried a passenger a distance of three-quarters of a mile, and on October 30 made the first journey by aëroplane, from place to place, namely from Chalons to Rheims, a distance of 17 miles, and in so doing was obliged to rise about 200 feet to clear some tall poplars. Delagrange became enthusiastic over the possibilities of the aëroplane, and after making some records in France exhibited the Voisin machine in Italy. At Milan, on June 22, 1908, he made a flight of 10½ miles in sixteen minutes, the longest flight which had yet been made in public.

The Voisin machine, which is represented in flight in Fig. 31, consists essentially of two pairs of sustaining surfaces, aggregating 560 square feet, and a motor. The front part, containing the motor, has two superposed surfaces, slightly arched, and five feet apart, with a width of six and one-half feet and a span of 43 feet, to which a rear cell with movable sides is connected by longitudinal strips and steel stays. Behind the 40-horse-power Antoinette motor is the screw and in front is a horizontal rudder. The whole is mounted on

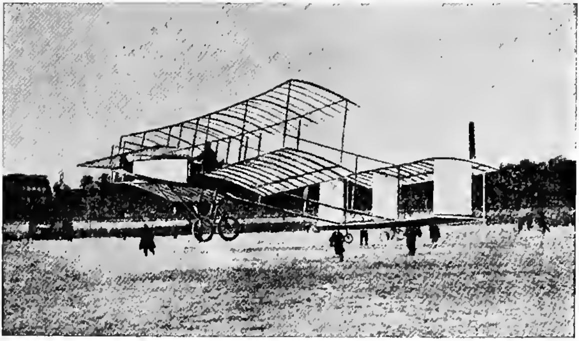

FIG. 31.—Voisin Aëroplane in Flight.

four bicycle wheels, the front pair having strong springs to decrease the shock of landing. The pilot, seated in front of his motor, manipulates a wheel which gives a double direction: to the right or left by cords acting on the rear cell, and up or down by slanting the horizontal steering-plane in front.

The success of the dirigible balloon abroad, and the advent of aviation in France caused the Chief Signal Officer of the United States Army, in December, 1907, to invite bids for a dirigible balloon and for a heavier-than-air flying-machine, with a view to develop practical aviation in this country, and to supply the War Department with machines for military service. The former has been described in the last chapter. The specifications for the latter required the machine to carry one passenger besides the aviator, to remain in the air on an endurance test for a period of one hour without landing, and be subjected to a speed test over a measured course of more than five miles, against and with the wind, attaining a maximum speed of 36 miles per hour. The machine was to carry fuel for a continuous flight of not less than 125 miles. At that time the conditions were regarded as severe, and beyond what had been accomplished. Nevertheless, bids were received from the Wright brothers to furnish a machine having a speed of 40 miles for the sum of $25,000, and from A. M. Herring of New York for one costing $20,000. The Wrights, having constructed a motor-flyer, proceeded to try it on the North Carolina coast, the place of their former experiments, in May, 1908. The trials were witnessed by newspaper correspondents, and one flight of five miles was made in seven and one-half minutes.

About the same time a French syndicate purchased the Wright patents in France, for the sum of $100,000, conditional on two flights of 31 miles in one hour each, carrying a passenger and sufficient fuel for a voyage of 125 miles, and Wilbur Wright, the elder of the brothers, went to France to make these demonstrations, the race course near Le Mans being chosen as the place for the experiments. The first flight was made August 8, 1908, in the presence of many French aviators, and flights were continued until the end of the year at the Camp of Auvours, during which Wilbur Wright not only fulfilled the conditions imposed by the syndicate, but also won several aviation prizes, and beat the French records for duration, distance, and height of flights. Then on September 21, 42 miles were accomplished in one hour and thirty-one minutes, and on October 10 a flight of more than an hour was made with a passenger. Many passengers, including ladies, were taken up. On one occasion the height of 380 feet was reached and finally, on the last day of the year, all records for distance and duration were broken by a flight of 77 miles in two hours and twenty minutes.

Meanwhile Orville Wright had begun at Fort Myer, near Washington, the tests required by the War Department, and had made some flights of more than an hour. He had also carried separately two officers of the Signal Corps and on September 17 had as passenger Lieutenant Selfridge. When the machine was at an altitude of about 100 feet, one screw caught in a wire connecting the rudder and broke. The equilibrium was disturbed and the machine fell to the ground with violence, killing Lieutenant Selfridge and seriously injuring Mr. Wright. This accident put an end to the trials, but the Government, satisfied that the machine could fulfill the conditions imposed, extended the time limit to the following year.

The appearance and construction of the

FIG. 32.—Wright Aëroplane in Position to Start.

Wright biplane are evident from the frontispiece, which shows it in a flight at Fort Myer, on September 9, 1908, and from Figs. 32 and 33, representing it on the ground. A remarkable fact about the Wright machine is that it has undergone practically no change of construction since it was first designed in 1903, showing the care with which all the details were studied.

The Wrights are the first aviators who have dared suppress all methods of automatic equilibrium, such as tail, vertical keel, etc. Their aëroplane has two superposed curved surfaces, six feet apart, with a spread of 40 feet and a width of six and one-half feet from front to rear. Like the Voisin machine the framework is of wood covered with cloth. The area of this double supporting surface is about 500 square feet, and the surfaces are so constructed that their extremities can be warped at the will of the operator. It is the flexibility of the wings which constitutes the chief feature of this model, although this was originated by Le Bris in 1867. A horizontal rudder of two superposed plane surfaces about 15 feet long and three feet wide is placed in front of the main surfaces. Behind the main planes is a vertical rudder formed of two surfaces trussed together about five and one-half feet long and one foot wide. The auxiliary surfaces and the mechanism controlling the warping of the main surfaces are operated by two levers. One of these levers at the right of the pilot permits the ends of the rear portion of the supporting surfaces to be warped, one side rising as the other side sinks, and also at the same time, by moving the lever in another plane, displaces the rear vertical rudder. Another lever at the left of the pilot varies the angle of incidence of the horizontal rudder in front and so changes the vertical motion of the machine. All the levers and transmission rods are of wood, except the shafts and supports for the screw propellers. Steel wires unite and stiffen the various members.

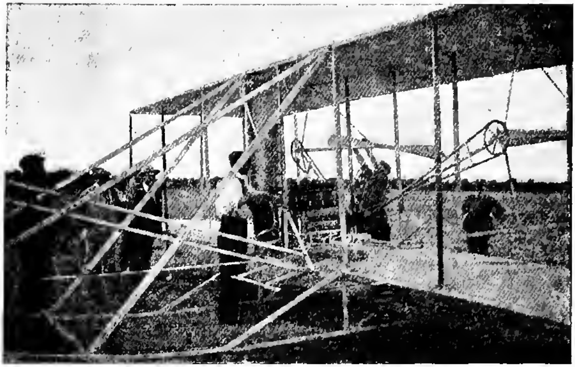

Fig. 33.—Details of Wright Aëroplane.

The motor, designed by the Wrights, has 4 cylinders, is water-cooled, and develops about 25 horse-power. There are two wooden propellers, placed behind the main supporting surfaces, driven by chain transmission in opposite directions at about 400 revolutions per minute. (See Fig. 33). The engine and radiator are placed on the right of the lateral center of gravity, and the operator sitting on the left side exactly balances their weight, so that the passenger sitting over the center does not change at all the balance. The machine is supported on two runners and weighs about 800 pounds. Unlike the French apparatus mounted on wheels, the Wright aëroplane is launched by the folowing method: Supported on a light chariot the machine is wheeled from its shed to the end of a rail 80 feet long, and if the wind is light is connected with a 1,500-pound weight, hoisted to the top of a 20-foot pyramid by means of a rope which, running beneath the rail passes over a pulley and returns to the front of the machine. (See Fig. 32). The screws being started the pilot releases the catch which holds the machine to the rail and at the same time causes the weight to drop. This, acting through the rope, draws the aëroplane forward with an accelerated velocity which at the end of the rail is sufficient, when the rope is automatically unhooked and the vertical rudder turned upward, to propel the machine into the air, through which it continues to fly by the action of its screws. If the wind is strong the machine can travel against it on the rail by the sole action of the screws without using the weight. The descent at a small angle is effected by lowering the forward rudder, and when a few yards above the ground the engine is stopped and the aëroplane is turned upward against the wind. Now it completely loses its horizontal velocity and, its vertical speed being slight, the runners may touch the ground and the machine come to rest within two or three yards, without shock, and exactly like a bird alighting. In horizontal flight the front rudder must be constantly maneuvered to accommodate the machine to the waves of the air, and in making the turns the lever governing the rear rudder and the wings must be manipulated so as to incline the aëroplane down toward the center of the circle, like a bicycle rounding a curve.

The piloting of this flyer requires experience and skill, and a comparison with the Voisin construction shows that the latter is much easier to manage, as proved by the fact that Farman and Delagrange, novices in aviation, flew almost immediately. Owing to the good proportions of the Voisin aëroplane it is automatically stable, against rolling, pitching, and in turning, unless the air is very much agitated. Its wings are fixed and slightly concave above, thereby promoting equilibrium laterally, and this is secured longitudinally by a tail placed at a considerable distance from the main supporting surfaces. The pilot of a Voisin flyer has only to do two things, change the angle of the horizontal rudder to rise or fall, and incline the vertical rudder in the tail to make a turn. But this ease of management has several drawbacks. First the Voisin model is heavier than the Wright, it rises slower and alights less gently, while its turnings are wider and less easily made. Finally and most important, it offers greater resistance to forward motion, requiring a more powerful motor (40 horse-power as compared with 25) and that is why, notwithstanding the higher speed (44 miles per hour compared with 37), the failures of the motor have left Farman and Delagrange far behind the Wrights, both in duration and distance, as the records already cited show.

As to the relative danger of the two types, there is little difference. In case of the motor stopping, either machine should descend at a gentle angle and alight on level ground without injury, but while the maneuver is easier in the Voisin flyer, the Wright flyer is capable of landing more gently. As Wilbur Wright remarked to the author after the accident to his brother, it is advantageous in case of accident to be either very near the ground or else so high as, in case of stoppage of the motor, to be able to select the landing place while descending at an angle of 1 in 8. Although the use of two screws gives stability to the aeroplane, the breakage of either of them, or of the transmission-chains, may wreck the machine, unless equilibrium can be regained before the ground is reached, and it will be remembered that this was not done in the catastrophe at Fort Myer. If we compare the aspect of the two machines in flight, the Wright, with its gentle pitching, seems to be a bird riding on the air, while the Voisin, with its long tail, pursues its trajectory like an arrow. It may be said that both the Wright and the Voisin flyers were evolved independently from the Lilienthal-Chanute gliders, to which the Wrights were the first to apply a motor.

The French monoplanes, on the contrary,

were the outcome of the Langley-Ader experiments, and while it is true that the biplanes have given the best results, yet the majority of French aviators have adopted the monoplane. Esnault-Pelterie was one of the early experimenters, and his machine, shown in Fig. 34, resembles a great butterfly. The body, shaped like a cigar, contains the 30-horse-power motor and the pilot, and on the ground is supported on two tandem wheels with two others at the ends of the wings whose curvature can be altered. The four-bladed propeller is in front and a horizontal rudder at the rear can be shifted both transversely and vertically. In starting, the machine rests on the central wheels and on the wheel attached to one of the wings, but when sufficient velocity is gained the aëroplane rights itself and rises, flying at a speed of 35 miles per hour. The characteristics of the monoplanes are that with the same motive force they attain a greater velocity than biplanes, but on the other hand, their equilibrium is more delicate, so that turns are dangerous and they are upset by a violent landing.

Blériot has built several monoplanes, and one of the Langley type, with a pair of wings slightly divergent like a dragon-fly's, flew 600 feet at a height of 50 feet. A later model was able to make turns safely by means of steadying planes at the extremities of the wings, and flew more than 3 miles at the rate of 52 miles an hour, the greatest speed yet attained by an aërial machine, thus proving that a monoplane may compete with the best biplanes. In October, 1908, Blériot flew from one village to another on the plain of Beauce, and executed a trip of 17 miles across country in a closed circuit, with three intermediate landings, at a maximum speed of 50 miles an hour. Many methods have been employed to give stability to the monoplane, such as a long horizontal tail to counteract pitching, a vertical keel, dihedral angles between the wings, which are turned upward by Blériot and downward by Esnault-Pelterie. An ingenious monoplane of extreme lightness has just been tried by Santos-Dumont. It is built of canvas and bamboo, weighs only 330 pounds including the aviator, and is provided with a 24-horse-power engine which gives a speed of 45 miles an hour. It has the advantage that it may be taken apart and carried on a motor car. The partisans of the monoplane point to the fact that no bird has superposed wings, and there seems to be a belief that, if this construction can be made stable, without greatly increasing the resistance, it will be the king of the air.

Besides the motor-monoplanes and biplanes there are triplanes and multiplanes. An interesting example of the former is the Danish triplane of Ellehammer, having three pair of triangular wings with the screw in front and a low center of gravity. Although many small helicopters have been constructed, it is only recently that one of them, built by Richet and Bréguet brothers, has been able to lift itself and a passenger off the ground.

While the Wright aëroplane is the best known, and perhaps the best of the American machines, that of Herring, an aviator early associated with Chanute, who claims to have used a motor before the Wrights, awaits trial by our Government. It is known to have a gyroscopic device for maintaining equilibrium, and a motor of extreme lightness.

Several biplanes have been constructed in America by the Aërial Experiment Association, which was founded and supported by Dr. A. Graham Bell. One of them called *June Bug*, shown in Fig 35, has two superposed curved surfaces, converging towards the wing-tips, giving a total supporting surface of 370 square feet. The tail, of the box type with a vertical rudder above the rear edge, and a horizontal rudder placed in front of the main surfaces, are both operated by a steering wheel. For maintaining transverse equilibrium there are four triangular wing-tips pivoted along their front edges, which are warped by a cord attached to the body of the operator. A 25-

FIG. 35.—*June Bug* in Flight.

horse-power, 8-cylinder, air-cooled Curtiss motor, drives a wooden propeller, 6 feet in diameter, placed between the main surfaces, about 1200 turns a minute. The total weight of the machine with aviator is 650 pounds, and it is mounted on two pneumatic-tired bicycle wheels. With this flyer G. H. Curtiss won the *Scientific American* trophy on July 4, 1908, traveling more than a mile at Hammondsport, New York, at a speed of about 39 miles an hour, when the photograph reproduced above was taken. A later flyer, the *Silver Dart,* designed by J. A. D. McCurdy, has circled over the ice in Baddeck Bay, Nova Scotia, nearly six miles in about eight minutes.

One condition imposed by the Weiller syndicate was that Wilbur Wright should train three pupils in the use of his machine, and this he has done during the past winter at Pau. Two of them, namely Paul Tissandier and Count de Lambert, are now each able to take a passenger over the circular course when the wind does not exceed 10 or 12 miles an hour, Wright himself having flown with a wind of 15 or 20 miles per hour, and carried two passengers. It is a significant fact that several prominent French aviators, such as Delagrange, Gasnier, and Kapferer, are learning to operate the Wright biplane, of which the manufacture has been begun by several French constructors, and it is expected that concessions for other countries will soon be granted. In France, at the present time, it is sold at the price of $6,000. In England, where the military dirigible balloon was a failure, many inventors are working on aëroplanes, stimulated by prizes offered by newspapers and societies.

In conclusion, we will briefly compare the dirigible balloon with the flying-machine. The great size of the former, its vulnerability, the large house which is required for its shelter with the difficulties of leaving and entering it, together with the cost of these expeditions, are disadvantages which cannot be overcome. But of vital importance is the fact that the speed cannot be greatly increased so as to render it independent of wind, whereas Langley has shown that the supporting area of an aëroplane varies inversely as the square of the velocity. This paradoxical statement is thus explained by Major Baden-Powell: " If a plane of given weight and area be set at a fixed angle of inclination and driven horizontally at such a rate that it is supported, it will absorb a certain force. If the speed be increased, of course the force will also have to be increased; this, however, gives a greater lift; but a greater lift is not required, and, therefore, either the area presented or the angle of inclination can be reduced and yet the weight of the apparatus be upheld. By reducing either of these the forward resistance is reduced, hence also the requisite power. Therefore, with less expenditure of power the aeroplane is upheld at a greater speed." This means that with a Wright aëroplane which has at present 500 square feet of wing surface, and a speed of 40 miles an hour, if the speed is increased to 60 miles per hour this area need be less than one-half its present size, while at 100 miles per hour only 80 square feet of supporting surface is required. It will be observed that the discarded area, equivalent to 420 square feet of the original supporting surface, may be utilized to provide a more powerful engine capable of imparting to the smaller aeroplane an increased speed.

The chief superiority of the balloon, apart from the inherent safety due to its buoyancy, is that it can carry a heavier load, including a more reliable motor. But even to-day, for the use of one or two persons, and for short excursions near the ground the aëroplane, although still in its infancy, is faster, more easily maneuvered, and very much cheaper to build and operate than the dirigible balloon.

CHAPTER V

THE FUTURE OF AËRIAL NAVIGATION

WITH the accomplishment of human flight by machines heavier than air, and the improvement of the dirigible balloon, it is natural that speculation should be rife concerning the influence which aërial navigation may have on mundane affairs.

Although the facility of traversing the atmosphere more or less freely in three dimensions is now afforded, this is less startling than was the opening of the vast depth of the atmosphere to exploration by the invention of the balloon 126 years ago. At that time public interest in France was greatly excited by the wonderful extension of the realm of man, and the famous Lavoisier was asked by the Academy of Sciences to draw up a report on the value of the new discovery, but it is related that the great chemist was unable to enumerate the multitude of problems which the balloon could solve. As we now know, however, the free balloon has been of little use except as a means of exploring the atmosphere.

We can easily understand that with the acquisition of this new field of locomotion which dominated land and water the direction of the balloon seemed easy and its uses many, and they were thus described by an unknown French author in 1783: "For peaceful purposes there may be specified:—Making maps, signaling at great distances, communicating with distant countries, making astronomical observations above the smoke and haze and with a wider horizon, etc. For comfort and pleasure there never was a more prolific invention than the balloon. No one will go on foot when a carriage can be had so cheaply. The air will furnish an easy route which does not need repairs and is never crowded. Finally the destructive agencies of the balloon are numerous, as is unfortunately the case with most of the great discoveries. Balloons will serve to cross rivers, to erect ambuscades, to surprise places, and to crush entire armies on the march, for a balloon 100 feet in diameter can sustain at a great height in the air a weight of several thousand pounds, and therefore can carry at least 10 soldiers with fire-grenades, and other modern missiles, which may be rained down upon the troops. Moreover, 200 balloons of this size could, in a few minutes, disembark in a besieged place 2,000 grenadiers with their arms, and ten minutes later might bring over a similar force. The cost is certainly less than that of batteries, and the fate of such places as Gibraltar would be certain."

Fanciful as these ideas were at that time, the assertions of the wonders which aërial navigation is going to work are even more bold to-day, and in this concluding chapter the possibilities of airships and flying machines will be considered in the light of expert and conservative opinion.

The predictions of the French writer at the end of the eighteenth century, concerning the balloon as an agent in warfare, are being revived almost *literatim* as constituting the chief application of the dirigible balloon. That this purpose is really being considered seriously is shown by the fact that each one of the principal military powers is actively developing this auxiliary as an adjunct to the military establishment. For example, Germany is reported to have spent $670,000 of the public funds in 1908 in experimenting in aërial navigation for military purposes; France, $280,000, and Austria and England, each about $27,000. Up to the present time the dirigible balloon has been chiefly considered because in its actual state of development the aëroplane does not lend itself to practical purposes. A suggestive report on the present status of military aëronautics has recently been prepared by Major George O. Squier, of the United States Signal Corps, in which he discusses the influence on the military art of airships and flying-machines. Major Squier points out that military maneuvers have been conducted hitherto in a plane where the armies concerned have been limited in their movements, both in time and place, by the physical character of the ground. The essence of strategy is surprise, and great victories must henceforth result in capture rather than killing, and be effected by forcing the enemy into untenable situations. The element of time has always been a controlling factor in warfare. It is often a military necessity to conduct a reconnoissance in force to develop the enemy's dispositions, and with efficient military airships these results may be attained with a very few men, and in a small fraction of the time heretofore required. In reconnoitering, dirigibles are obliged to maneuver at an altitude of about a mile, but with tele-photographic apparatus much detail of the ground can be obtained at that height. At night the dirigible may descend to within a few hundred feet of the earth with safety and thus obtain valuable information. Equipped with wireless telegraph or telephone apparatus, military data could be obtained and transmitted without undue risk, with the radius of action of the small dirigible of about 200 miles. Undoubtedly scouting is actually the chief rôle of the present military dirigible, but granting the possibility of launching explosives with effect from larger and faster balloons, capable of a greater radius of action, the airship may become a powerful engine of war, which may be used in all ordinary weather. By flying high in the air during the daytime, and descending at night, airships might launch explosives and produce great damage. Being able to pass over armies and proceed at great speed, their objective would not usually be the enemy's armies, but their effort would be to destroy the base of supplies. Whether it is possible to launch explosives with sufficient accuracy, using gravity as a motive force, is still doubtful, but, in any case, the number and weight of such projectiles are limited, and to counteract the rebound of the balloon after the discharge of each one, it is imperative to let gas escape and replace it with an equal volume of air. The weight and recoil of even small cannon charged with powder or compressed air will probably prevent their employment in aërial warfare to secure a higher velocity for the projectiles and avoid the necessity of coming directly over the object attacked.

Hitherto it has been the custom to protect the geographical limits of a country by fortresses, and, in time of war, excursions into the enemy's territory require the backing of a strong military force, but with a third dimension added to the theater of operations it will be possible to cross over the boundary on rapid raids for obtaining information, accomplishing demolition, etc., and return to safe harbors. One of the military objectives in warfare is usually the enemy's capital city, protected by armies which must be subdued before the city can be captured. With the advent of efficient airships, however, small parties of men may pass over the protective armies on expeditions aimed at the seat of government, so that now, for the first time, state officials, who are responsible for the war, may themselves be in danger after its declaration, which heretofore has not been usually the case. The moral effect of a hostile airship, seen above the enemy's country, constitutes a large part of its efficiency in warfare.

So long as the motor-balloon, or aëronat as it is technically called, remains in the air it may be regarded as tolerably safe, for even if its engines are disabled it can still serve as a free balloon. When brought in contact with the ground, however, it is in danger from high winds on account of its fragile structure and its momentum, especially if the balloon is large. Just as ships keep away from the coast in a storm, or enter port, so aëronauts must weather the gale above the earth or seek some sheltered harbor. These harbors may be natural ones, such as deep valleys surrounded by forests or other protection, or artificial ones, such as gravel pits or railway cuttings, where the aëronat may descend and be sheltered from the winds above. Their locations must be known to the pilot and will be indicated on the maps, together with the electric lines of high potential, furnaces, and other locations dangerous for landing in balloons. At night the harbors can be marked by searchlights projected vertically or by rockets discharged occasionally.

The flying-machines of to-day with their uncertain motors, their defective methods of launching and their unstable equilibrium, cannot be applied to offensive military purposes. Not one has yet risen 1,000 feet nor dared to venture over cities or seas. But all these defects are expected to be remedied in time, and the offer of prizes aggregating several hundred thousand dollars for the performance of journeys will stimulate inventors here and abroad.

While it is hazardous to predict the military uses of the perfected flying-machine, the chief rôle appears to be reconnoitering, provided it can rise high enough to escape musketry-fire, that is, at least a quarter of a mile, where it would still be in considerable danger. To observe well when moving fifty miles an hour it is necessary to be high up, and this will always be difficult for flying-machines, first because of the diminished air-pressure on the sustaining surfaces, and second because of the lessened quantity of oxygen to feed the motor. It is probable, therefore, that aëronefs will merely serve for making brief and definite reconnaissances, and as a means of communication over short distances they may completely replace aëronats, which require a larger crew, and are with difficulty housed and protected from the wind. Flying-machines will hardly be used to attack an adversary by launching aërial torpedoes, since, as we have seen in the last chapter, they must always remain of small carrying capacity.

The dirigible balloon will not only be useful to armies in the field and to fortresses, but it can also be attached with advantage to seaports and even fleets; for more important than in land campaigns is the necessity of reconnoitering in naval warfare. A dirigible balloon, moving faster than the fastest torpedo boat, can extend its investigation over a large radius and report the presence and strength of the enemy's ships to flagship or naval base while they are still far distant. Moreover, since high above the surface of the sea its depths can be plainly discerned, the dirigible is in a position to discover a submarine vessel or a mine which would be invisible from the surface itself, even were it quite smooth. In certain cases explosive projectiles might be dropped upon a vessel if its deck was not armored, but the projectile itself, having only the velocity due to gravity, would possess slight power of penetration, and the aim, when both ship and airship were in motion, would necessarily be bad.

In view of the possibility of this method of aërial attack on land or sea it is unfortunate that at the Second International Peace Congress at The Hague in 1907, the United States was alone among the other first-class powers to agree to prohibit for a further period, extending to the next Conference, the discharge of projectiles and explosives from balloons or by other new methods of a similar nature. A previous agreement was ratified to forbid the bombardment, in any manner, of towns or buildings which are not defended.

An aëronat operated from a floating base presents difficulties and would require a shed to be built upon the hull of a vessel. The use of aëroplanes at sea seems possibly feasible; perhaps a device in the nature of a helicopter would be necessary to rise from or alight on the deck of a vessel.

In the absence of actual tests the efficacy of any defense against airships can only be conjectured, but if they should come into general use, no doubt special forms of artillery will be devised for their destruction. Already the firm of Krupp has constructed field cannon permitting a high angle of elevation over a wide range in azimuth to be obtained rapidly, but, nevertheless, this and the extreme vulnerability of a motor-balloon are offset by the difficulty of hitting a target which is changing rapidly its position and height, while projectiles fired towards the zenith might be more dangerous to friend than foe by the falling fragments. Possibly, airships will be fought by airships and aëroplanes and victory will then rest with the one having the greatest speed or maneuvering most rapidly, but the opinion of a conservative writer like Professor Newcomb is that a conflict between two aërial navies belongs to the realm of poetry, for it will be remembered that Tennyson wrote:

"Heard the heavens fill with shouting, and there rained a ghastly dew
From the nations' airy navies grappling in the central blue."

If, however, this should come to pass it would seem that there must be an extraordinary disparity of force did not mutual annihilation speedily result and a few minutes suffice to send both combatants down to earth or ocean.

That the nations of Europe are keenly alive to the possibility of using airships and aëroplanes in warfare is shown by the haste to acquire them by the military authorities of the chief countries, and the formation of popular Aërial Leagues of Defense in Germany, France, England, and Switzerland. Another indication of the growing interest in aëronautics is the establishment of courses of instruction in technical schools and universities in this country and abroad.

To form an idea of the general uses to which aëronats or aëronefs may be put we should consider first their possibilities and limitations. The speeds which can be attained by machines immersed in air are much higher than are possible for those floating in water. According to Major Squier the power required to overcome friction due to forward motion will be about one-eighth as much for a vessel in air as for a vessel of the same weight in water, that is, a dirigible balloon carrying the same weight, other things being equal, may be made to travel about twice as fast as a boat of the same power, or be propelled at the same speed with the expenditure of one-eighth the power. In order to overcome the usual winds the airship should have a proper speed of about 50 miles per hour, that is, be provided with about as much power as would drive a boat, carrying the same weight, 25 miles per hour, which is the same ratio of power to size obtaining in the fastest ocean steamships.

Since, in the balloon, the carrying capacity is proportional to the volume, which increases as the cube of the surface and weight, and these increase only as the square of linear dimensions, there is an advantage in large dirigibles, whereas, since in the aëroplane the weight for equal strength increases faster than the supporting surface, the smaller aëroplanes are most efficient. If both fundamental forms of aërial craft are developed, the lighter-than-air type, or aëronat, will be the burden-bearing machines of the future, whereas the heavier-than-air type, or aëronef, will be limited in size and will move at a high speed.

While the former may have its uses, the latter will generally supplant it. By increasing the speed of the aëroplane, the area of the supporting surfaces is reduced until it practically disappears, and we have a machine propelled by great power, supported largely by the pressure against its body, and with its wings reduced to mere fins which serve to guide and steady its motion. To perfect the flying-machine the following improvements are necessary:

1. A light motor, operating absolutely reliably and without heating.

2. The possibility of installing two independent motors driving separate screws, so that the machine can be driven by either in case of a stoppage of the other.

3. Automatic stability in both lateral and longitudinal directions, so that the operator may be relieved from the thought of balance, and that in case of injury to him or the machine, it will glide safely to earth.

4. A practical method of launching, which requires neither a special apparatus nor a large surface of ground to start or land. This, perhaps, may be accomplished by a combination of aëroplane and helicopter.

5. Increase of efficiency, so that several persons with fuel and provisions may be carried.

6. Increase of velocity to at least 100 miles

an hour to be independent of any ordinary winds.

7. The possibility of slowing up or stopping in the air, perhaps also to be realized by a "helicoplane."

The dirigible balloon has probably nearly reached the limits of its development, and, although its size and speed may be increased with advantage, it will not come into general use on account of the cost of construction, operation, and maintenance.

All the evidence now at hand indicates that neither class of aërial craft will ever compete with railroads or ships as commercial carriers. For the balloon this is evident if we consider that merely to sustain a ton of cargo in the air at the height of a mile, more than 40,000 cubic feet of hydrogen, costing nearly $200, are required, without counting the aëronat itself and its propulsion forward. It is conceivable that an aëroplane having a proper speed of 100 miles per hour might carry the mails in a straight, or "air" line between places with tolerable regularity, and that two or three passengers might be taken also. But this method of public conveyance of passengers or parcels is not likely to assume large proportions, for there will always be an element of danger as well as delay. It appears certain that the carrying capacity of an aëroplane will remain small because, for equal strength and with concentrated loads, the weight increases as the cube of the dimensions, while the supporting surface only increases as the square. Nevertheless, when higher speeds become safe the dimensions may actually decrease, because, according to the principle explained in the last chapter, if the weight remains the same, the force required to sustain inclined planes in horizontal motion diminishes, instead of increasing, when the velocity is augmented. Still the power required will always be great, about *a* horse-power to each hundred pound's weight, and hence fuel, which in the Wright machine amounts to nearly one pound of gasoline per horse-power per hour, cannot be carried for long journeys. On account of the relatively small quantity of supplies which can be carried by any heavier-than-air machine, the exploration of polar seas or the interior of continents can better be performed by motor-balloons.

Aëronefs promise to be used for sport and pleasure much in the same way as automobiles are now, since they possess the advantage over present vehicles of being absolutely independent of the nature of the ground over which they travel. Therefore, they can go in a straight line, regardless of the topography of the country, surmount hills or low mountain ranges, and cross tolerably large bodies of water, while taking the shortest route between the points of departure and destination. Until means are devised for starting and landing in restricted areas this cannot be done within cities, or in mountainous or wooded regions; but, as regards the cities, platforms for this purpose may eventually be provided upon the roofs of our houses. Undoubtedly the danger to life and property in towns will be considerable and this may tend to prevent their use in congested districts.

Evidently aërial transit may facilitate law-breaking in certain ways. For instance, it will be difficult to maintain a customs service on frontiers which can be traversed at a great height and by night, and perhaps this freedom of the air will bring about free trade among the nations. The law of trespass must be amended to limit the extent of ownership above real estate, and in the future in may be as necessary to secure roofs against thieves as it is to-day the doors and windows of our buildings. But on the whole we can agree with Mr. Chanute that, while dirigible balloons and flying machines constitute a great mechanical triumph for man, they are not likely to upset materially existing conditions of life, as is frequently predicted. Their design and performance will doubtless be improved from time to time, and they will probably develop new uses of their own which have not yet been thought of.

At the International Congress of Aëronautics, held in connection with the Paris Exposition of 1900, the delegates of the United States government were Professor Langley and the author. The president of the Congress, Dr. Janssen, director of the Astrophysical Observatory at Meudon, like Professor Langley, was a firm believer in the speedy accomplishment of aërial locomotion, but unfortunately both these distinguished physicists died before they had seen men perform mechanical flight. In the light of subsequent progress, the prophetic vision of the age of aërial navigation, which Dr. Janssen described in his address to the Congress in the following sentence, to-day appears like the handwriting on the wall to disturb the peace of mind of Great Britain, secure hitherto in her insularity:

"Themistocles said: 'He who shall make himself master of the sea is destined to become master of the land.' Now if the ocean has given this power to the nation that was wise enough to seize it, how much greater will be the coming mistress of the air? While the sea separates and renders passage of even a narrow channel difficult in the face of a hostile force, the air unites all nations and offers a route from any point on the earth's surface to any other, which can be traversed with impunity, no matter how vigilant the patrol. Political or natural frontiers will no longer form barriers between states when aërial fleets can sail over them."

The advent of aërial navigation does not find Dr. Janssen's hope realized that the conquest of the air might come when civilization has reached such a high plane that it will recognize justice, right, and peace as alone consistent with the welfare of mankind. But, while it may not lead to Utopia, the entry of man into a domain to which Nature seemed to have denied him access forever, will certainly constitute, by virtue of the constancy and intensity of the efforts that it will have cost, and by the discoveries and inventions which it will have provoked, one of the highest titles to glory of which the human race will be able to boast.

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