**FLYING MACHINE:**

**CONSTRUCTION AND OPERATION**

**By W.J. Jackman and Thos. H. Russell**

**FLYING MACHINE: CONSTRUCTION AND OPERATION**

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A Practical Book Which Shows, in Illustrations, Working Plans and Text, How to Build and Navigate the Modern Airship.

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and

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With Introductory Chapter By Octave Chanute, C.E., President Aero Club of Illinois

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**PREFACE.**

This book is written for the guidance of the novice in aviation—the man who seeks practical information as to the theory, construction and operation of the modern flying machine. With this object in view the wording is intentionally plain and non-technical. It contains some propositions which, so far as satisfying the experts is concerned, might doubtless be better stated in technical terms, but this would defeat the main purpose of its preparation. Consequently, while fully aware of its shortcomings in this respect, the authors have no apologies to make.

In the stating of a technical proposition so it may be clearly understood by people not versed in technical matters it becomes absolutely necessary to use language much different from that which an expert would employ, and this has been done in this volume.

No man of ordinary intelligence can read this book without obtaining a clear, comprehensive knowledge of flying machine construction and operation. He will learn, not only how to build, equip, and manipulate an aeroplane in actual flight, but will also gain a thorough understanding of the principle upon which the suspension in the air of an object much heavier than the air is made possible.

This latter feature should make the book of interest even to those who have no intention of constructing or operating a flying machine. It will enable them to better understand and appreciate the performances of the daring men like the Wright brothers, Curtiss, Bleriot, Farman, Paulhan, Latham, and others, whose bold experiments have made aviation an actuality.

For those who wish to engage in the fascinating pastime of construction and operation it is intended as a reliable, practical guide.

It may be well to explain that the sub-headings in the articles by Mr. Chanute were inserted by the authors without his knowledge. The purpose of this was merely to preserve uniformity in the typography of the book. This explanation is made in justice to Mr. Chanute.

THE AUTHORS.

**CONTENTS**

**CHAPTER I. EVOLUTION OF TWO-SURFACE FLYING MACHINE.**

**By Octave Chanute.**

I am asked to set forth the development of the "two-surface" type of flying machine which is now used with modifications by Wright Brothers, Farman, Delagrange, Herring and others.

It is described as follows:

"Two or more aeroplanes are arranged one above the other, and support a framework or car containing the motive power. The aeroplanes are made of silk or canvas stretched on a frame by wooden rods or steel ribs. When manual power is employed the body is placed horizontally, and oars or propellers are actuated by the arms or legs.

"A start may be obtained by lowering the legs and running down hill or the machine may be started from a moving carriage. One or more screw propellers may be applied for propelling when steam power is employed."

Second Wenham Aeroplane.

His second aeroplane was sixteen feet from tip to tip. A trussed spar at the bottom carried six superposed bands of thin holland fabric fifteen inches wide, connected with vertical webs of holland two feet apart, thus virtually giving a length of wing of ninety-six feet and one hundred and twenty square feet of supporting surface. The man was placed horizontally on a base board beneath the spar. This apparatus when tried in the wind was found to be unmanageable by reason of the fluttering motions of the fabric, which was insufficiently stiffened with crinoline steel, but Mr. Wenham pointed out that this in no way invalidated the principle of the apparatus, which was to obtain large supporting surfaces without increasing unduly the leverage and consequent weight of spar required, by simply superposing the surfaces.

This principle is entirely sound and it is surprising that it is, to this day, not realized by those aviators who are hankering for monoplanes.

Experiments by Stringfellow.

The next man to test an apparatus with superposed surfaces was Mr. Stringfellow, who, becoming much impressed with Mr. Wenham's proposal, produced a largish model at the exhibition of the Aeronautical Society in 1868. It consisted of three superposed surfaces aggregating 28 square feet and a tail of 8 square feet more. The weight was under 12 pounds and it was driven by a central propeller actuated by a steam engine overestimated at one-third of a horsepower. It ran suspended to a wire on its trials but failed of free flight, in consequence of defective equilibrium. This apparatus has since been rebuilt and is now in the National Museum of the Smithsonian Institution at Washington. Linfield's Unsuccessful Efforts.

Hargrave's Kite Experiments.

After experimenting with very many models and building no less than eighteen monoplane flying model machines, actuated by rubber, by compressed air and by steam, Mr. Lawrence Hargrave, of Sydney, New South Wales, invented the cellular kite which bears his name and made it known in a paper contributed to the Chicago Conference on Aerial Navigation in 1893, describing several varieties. The modern construction is well known, and consists of two cells, each of superposed surfaces with vertical side fins, placed one behind the other and connected by a rod or frame. This flies with great steadiness without a tail. Mr. Hargrave's idea was to use a team of these kites, below which he proposed to suspend a motor and propeller from which a line would be carried to an anchor in the ground. Then by actuating the propeller the whole apparatus would move forward, pick up the anchor and fly away. He said: "The next step is clear enough, namely, that a flying machine with acres of surface can be safely got under way or anchored and hauled to the ground by means of the string of kites."

The first tentative experiments did not result well and emphasized the necessity for a light motor, so that Mr. Hargrave has since been engaged in developing one, not having convenient access to those which have been produced by the automobile designers and builders.

Experiments by the Writer.

In 1896, assisted by Mr. Herring and Mr. Avery, I experimented with several full sized gliding machines, carrying a man. The first was a Lilienthal monoplane which was deemed so cranky that it was discarded after making about one hundred glides, six weeks before Lilienthal's accident. The second was known as the multiple winged machine and finally developed into five pairs of pivoted wings, trussed together at the front and one pair in the rear. It glided at angles of descent of 10 or 11 degrees or of one in five, and this was deemed too steep. Then Mr. Herring and myself made computations to analyze the resistances. We attributed much of them to the five front spars of the wings and on a sheet of cross-barred paper I at once drew the design for a new three-decked machine to be built by Mr. Herring.

Being a builder of bridges, I trussed these surfaces together, in order to obtain strength and stiffness. When tested in gliding flight the lower surface was found too near the ground. It was taken off and the remaining apparatus now consisted of two surfaces connected together by a girder composed of vertical posts and diagonal ties, specifically known as a "Pratt truss." Then Mr. Herring and Mr. Avery together devised and put on an elastic attachment to the tail. This machine proved a success, it being safe and manageable. Over 700 glides were made with it at angles of descent of 8 to 10 degrees, or one in six to one in seven.

Monoplane Idea Wrong.

The advocates of the single supporting surface are probably mistaken. It is true that a single surface shows a greater lift per square foot than superposed surfaces for a given speed, but the increased weight due to leverage more than counterbalances this advantage by requiring heavy spars and some guys. I believe that the future aeroplane dynamic flier will consist of superposed surfaces, and, now that it has been found that by imbedding suitably shaped spars in the cloth the head resistance may be much diminished, I see few objections to superposing three, four or even five surfaces properly trussed, and thus obtaining a compact, handy, manageable and comparatively light apparatus. [2](https://www.gutenberg.org/files/907/907-h/907-h.htm%22%20%5Cl%20%22linknote-2)

**CHAPTER II. THEORY, DEVELOPMENT, AND USE.**

While every craft that navigates the air is an airship, all airships are not flying machines. The balloon, for instance, is an airship, but it is not what is known among aviators as a flying machine. This latter term is properly used only in referring to heavier-than-air machines which have no gas-bag lifting devices, and are made to really fly by the application of engine propulsion.

Mechanical Birds.

All successful flying machines—and there are a number of them—are based on bird action. The various designers have studied bird flight and soaring, mastered its technique as devised by Nature, and the modern flying machine is the result. On an exaggerated, enlarged scale the machines which are now navigating the air are nothing more nor less than mechanical birds.

Origin of the Aeroplane.

Octave Chanute, of Chicago, may well be called "the developer of the flying machine." Leaving balloons and various forms of gas-bags out of consideration, other experimenters, notably Langley and Lilienthal, antedated him in attempting the navigation of the air on aeroplanes, or flying machines, but none of them were wholly successful, and it remained for Chanute to demonstrate the practicability of what was then called the gliding machine. This term was adopted because the apparatus was, as the name implies, simply a gliding machine, being without motor propulsion, and intended solely to solve the problem of the best form of construction. The biplane, used by Chanute in 1896, is still the basis of most successful flying machines, the only radical difference being that motors, rudders, etc., have been added.

Character of Chanute's Experiments.

It was the privilege of the author of this book to be Mr. Chanute's guest at Millers, Indiana, in 1896, when, in collaboration with Messrs. Herring and Avery, he was conducting the series of experiments which have since made possible the construction of the modern flying machine which such successful aviators as the Wright brothers and others are now using. It was a wild country, much frequented by eagles, hawks, and similar birds. The enthusiastic trio, Chanute, Herring and Avery, would watch for hours the evolutions of some big bird in the air, agreeing in the end on the verdict, "When we master the principle of that bird's soaring without wing action, we will have come close to solving the problem of the flying machine."

Aeroplanes of various forms were constructed by Mr. Chanute with the assistance of Messrs. Herring and Avery until, at the time of the writer's visit, they had settled upon the biplane, or two-surface machine. Mr. Herring later equipped this with a rudder, and made other additions, but the general idea is still the basis of the Wright, Curtiss, and other machines in which, by the aid of gasolene motors, long flights have been made.

Developments by the Wrights.

In 1900 the Wright brothers, William and Orville, who were then in the bicycle business in Dayton, Ohio, became interested in Chanute's experiments and communicated with him. The result was that the Wrights took up Chanute's ideas and developed them further, making many additions of their own, one of which was the placing of a rudder in front, and the location of the operator horizontally on the machine, thus diminishing by four-fifths the wind resistance of the man's body. For three years the Wrights experimented with the glider before venturing to add a motor, which was not done until they had thoroughly mastered the control of their movements in the air.

Limits of the Flying Machine.

In the opinion of competent experts it is idle to look for a commercial future for the flying machine. There is, and always will be, a limit to its carrying capacity which will prohibit its employment for passenger or freight purposes in a wholesale or general way. There are some, of course, who will argue that because a machine will carry two people another may be constructed that will carry a dozen, but those who make this contention do not understand the theory of weight sustentation in the air; or that the greater the load the greater must be the lifting power (motors and plane surface), and that there is a limit to these—as will be explained later on—beyond which the aviator cannot go.

Some Practical Uses.

At the same time there are fields in which the flying machine may be used to great advantage. These are:

Sports—Flying machine races or flights will always be popular by reason of the element of danger. It is a strange, but nevertheless a true proposition, that it is this element which adds zest to all sporting events.

Scientific—For exploration of otherwise inaccessible regions such as deserts, mountain tops, etc.

Reconnoitering—In time of war flying machines may be used to advantage to spy out an enemy's encampment, ascertain its defenses, etc.

**CHAPTER III. MECHANICAL BIRD ACTION**

In order to understand the theory of the modern flying machine one must also understand bird action and wind action. In this connection the following simple experiment will be of interest:

Take a circular-shaped bit of cardboard, like the lid of a hat box, and remove the bent-over portion so as to have a perfectly flat surface with a clean, sharp edge. Holding the cardboard at arm's length, withdraw your hand, leaving the cardboard without support. What is the result? The cardboard, being heavier than air, and having nothing to sustain it, will fall to the ground. Pick it up and throw it, with considerable force, against the wind edgewise. What happens? Instead of falling to the ground, the cardboard sails along on the wind, remaining afloat so long as it is in motion. It seeks the ground, by gravity, only as the motion ceases, and then by easy stages, instead of dropping abruptly as in the first instance.

Here we have a homely, but accurate illustration of the action of the flying machine. The motor does for the latter what the force of your arm does for the cardboard—imparts a motion which keeps it afloat. The only real difference is that the motion given by the motor is continuous and much more powerful than that given by your arm. The action of the latter is limited and the end of its propulsive force is reached within a second or two after it is exerted, while the action of the motor is prolonged.

Another Simple Illustration.

Another simple means of illustrating the principle of flying machine operation, so far as sustentation and the elevation and depression of the planes is concerned, is explained in the accompanying diagram.

A is a piece of cardboard about 2 by 3 inches in size. B is a piece of paper of the same size pasted to one edge of A. If you bend the paper to a curve, with convex side up and blow across it as shown in Figure C, the paper will rise instead of being depressed. The dotted lines show that the air is passing over the top of the curved paper and yet, no matter how hard you may blow, the effect will be to elevate the paper, despite the fact that the air is passing over, instead of under the curved surface.

In Figure D we have an opposite effect. Here the paper is in a curve exactly the reverse of that shown in Figure C, bringing the concave side up. Now if you will again blow across the surface of the card the action of the paper will be downward—it will be impossible to make it rise. The harder you blow the greater will be the downward movement.

Diagram?

Principle In General Use.

This principle is taken advantage of in the construction of all successful flying machines. Makers of monoplanes and biplanes alike adhere to curved bodies, with the concave surface facing downward. Straight planes were tried for a time, but found greatly lacking in the power of sustentation. By curving the planes, and placing the concave surface downward, a sort of inverted bowl is formed in which the air gathers and exerts a buoyant effect. Just what the ratio of the curve should be is a matter of contention. In some instances one inch to the foot is found to be satisfactory; in others this is doubled, and there are a few cases in which a curve of as much as 3 inches to the foot has been used.

Right here it might be well to explain that the word "plane" applied to flying machines of modern construction is in reality a misnomer. Plane indicates a flat, level surface. As most successful flying machines have curved supporting surfaces it is clearly wrong to speak of "planes," or "aeroplanes." Usage, however, has made the terms convenient and, as they are generally accepted and understood by the public, they are used in like manner in this volume.

Getting Under Headway.

A bird, on first rising from the ground, or beginning its flight from a tree, will flap its wings to get under headway. Here again we have another illustration of the manner in which a flying machine gets under headway—the motor imparts the force necessary to put the machine into the air, but right here the similarity ceases. If the machine is to be kept afloat the motor must be kept moving. A flying machine will not sustain itself; it will not remain suspended in the air unless it is under headway. This is because it is heavier than air, and gravity draws it to the ground.

Modeled Closely After Birds.

So far as possible, builders of flying machines have taken what may be called "the architecture" of birds as a model. This is readily noticeable in the form of construction. When a bird is in motion its wings (except when flapping) are extended in a straight line at right angles to its body. This brings a sharp, thin edge against the air, offering the least possible surface for resistance, while at the same time a broad surface for support is afforded by the flat, under side of the wings. Identically the same thing is done in the construction of the flying machine.

Note, for instance, the marked similarity in form as shown in the illustration in Chapter II. Here A is the bird, and B the general outline of the machine. The thin edge of the plane in the latter is almost a duplicate of that formed by the outstretched wings of the bird, while the rudder plane in the rear serves the same purpose as the bird's tail.

**CHAPTER IV. VARIOUS FORMS OF FLYING MACHINES.**

There are three distinct and radically different forms of flying machines. These are:

Aeroplanes, helicopters and ornithopters.

Of these the aeroplane takes precedence and is used almost exclusively by successful aviators, the helicopters and ornithopters having been tried and found lacking in some vital features, while at the same time in some respects the helicopter has advantages not found in the aeroplane.

What the Helicopter Is.

The helicopter gets its name from being fitted with vertical propellers or helices (see illustration) by the action of which the machine is raised directly from the ground into the air. This does away with the necessity for getting the machine under a gliding headway before it floats, as is the case with the aeroplane, and consequently the helicopter can be handled in a much smaller space than is required for an aeroplane. This, in many instances, is an important advantage, but it is the only one the helicopter possesses, and is more than overcome by its drawbacks. The most serious of these is that the helicopter is deficient in sustaining capacity, and requires too much motive power.

Form of the Ornithopter.

The ornithopter has hinged planes which work like the wings of a bird. At first thought this would seem to be the correct principle, and most of the early experimenters conducted their operations on this line. It is now generally understood, however, that the bird in soaring is in reality an aeroplane, its extended wings serving to sustain, as well as propel, the body. At any rate the ornithoper has not been successful in aviation, and has been interesting mainly as an ingenious toy. Attempts to construct it on a scale that would permit of its use by man in actual aerial flights have been far from encouraging.



Three Kinds of Aeroplanes.

There are three forms of aeroplanes, with all of which more or less success has been attained. These are:

The monoplane, a one-surfaced plane, like that used by Bleriot.

The biplane, a two-surfaced plane, now used by the Wrights, Curtiss, Farman, and others.

The triplane, a three-surfaced plane This form is but little used, its only prominent advocate at present being Elle Lavimer, a Danish experimenter, who has not thus far accomplished much.

Differences in Biplanes.

While all biplanes are of the same general construction so far as the main planes are concerned, each aviator has his own ideas as to the "rigging."

Wright, for instance, places a double horizontal rudder in front, with a vertical rudder in the rear. There are no partitions between the main planes, and the bicycle wheels used on other forms are replaced by skids.

Voisin, on the contrary, divides the main planes with vertical partitions to increase stability in turning; uses a single-plane horizontal rudder in front, and a big box-tail with vertical rudder at the rear; also the bicycle wheels.

Curtiss attaches horizontal stabilizing surfaces to the upper plane; has a double horizontal rudder in front, with a vertical rudder and horizontal stabilizing surfaces in rear. Also the bicycle wheel alighting gear.



**CHAPTER V. LEARNING TO FLY.**

Don't be too ambitious at the start. Go slow, and avoid unnecessary risks. At its best there is an element of danger in aviation which cannot be entirely eliminated, but it may be greatly reduced and minimized by the use of common sense.

Theoretically, the proper way to begin a glide is from the top of an incline, facing against the wind, so that the machine will soar until the attraction of gravitation draws it gradually to the ground. This is the manner in which experienced aviators operate, but it must be kept in mind that these men are experts. They understand air currents, know how to control the action and direction of their machines by shifting the position of their bodies, and by so doing avoid accidents which would be unavoidable by a novice.

Begin on Level Ground.

Make your first flights on level ground, having a couple of men to assist you in getting the apparatus under headway. Take your position in the center rectangle, back far enough to give the forward edges of the glider an inclination to tilt upward very slightly. Now start and run forward at a moderately rapid gait, one man at each end of the glider assisting you. As the glider cuts into the air the wind will catch under the uplifted edges of the curved planes, and buoy it up so that it will rise in the air and take you with it.

Effect of Body Movements.

When the weight of the body is slightly back of the center of gravity the edges of the advancing planes are tilted slightly upward. The glider in this position acts as a scoop, taking in the air which, in turn, lifts it off the ground. When a certain altitude is reached—this varies with the force of the wind—the tendency to a forward movement is lost and the glider comes to the ground. If you shift your body well forward it will bring the front edges of the glider down, and elevate the rear ones. In this way the air will be "spilled" out at the rear, and, having lost the air support or buoyancy, the glider comes down to the ground. A few flights will make any ordinary man proficient in the control of his apparatus by his body movements, not only as concerns the elevating and depressing of the advancing edges, but also actual steering. You will quickly learn, for instance, that, as the shifting of the bodily weight backwards and forwards affects the upward and downward trend of the planes, so a movement sideways—to the left or the right—affects the direction in which the glider travels.

Ascends at an Angle.

In ascending, the glider and flying machine, like the bird, makes an angular, not a vertical flight. Just what this angle of ascension may be is difficult to determine. It is probable and in fact altogether likely, that it varies with the force of the wind, weight of the rising body, power of propulsion, etc.