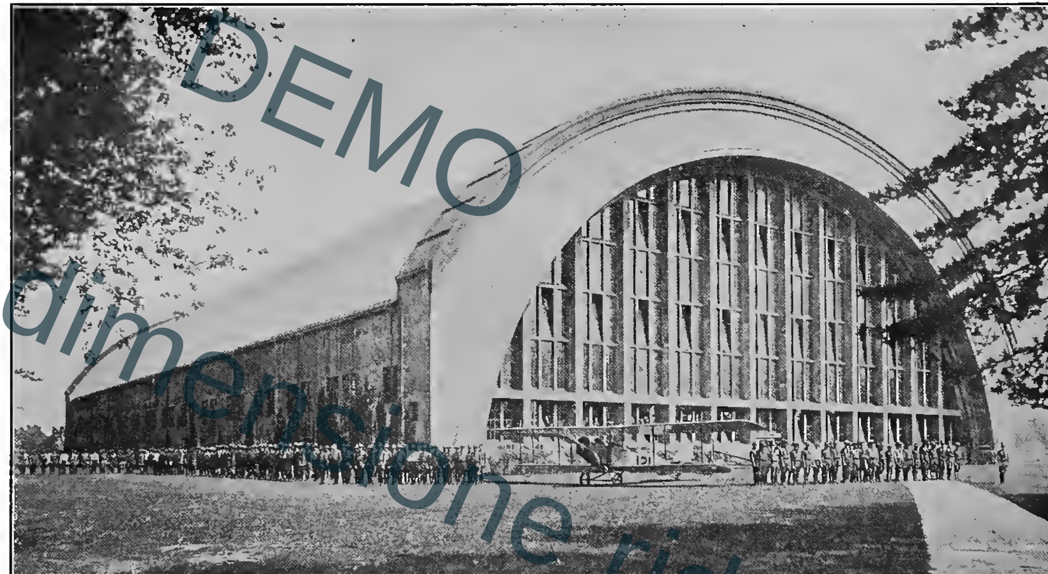


A GROUP OF U. S. ARMY STUDENT AVIATORS.

Frontispiece

PREFACE

This book is primarily intended for non-technical readers; and for the student aviators who, called from non-technical occupations, must cram themselves at short notice with the gist of airplane flying; and who must omit everything except the outstanding fundamentals.

The desired essentials are here given without sacrificing accuracy to brevity. It has been necessary to omit many technical details of interest to the aeronautical engineer, to whose needs other larger textbooks are adapted as a complete survey of technical aeronautics. In brief, the book presents the main principles of aviation, such as the aviator must know in order properly to understand his airplane, keep it trued up, and operate it in cross-country flights as well as at the flying field.

Out of the 2000 aeronautical books now in existence, a few are adapted to use as textbooks for the present need, but none give the particular and abridged information in tabloid form such as must be adopted for the best time economy of these students.

It is by the kind permission of Professor E. A. Holbrook, Mr. O. S. Beyer, and Mr. C. M. Hebbert that chapters VI to XI have been included. Acknowledgment and full credit is due them as co-authors. Chap. VI, VII, and part of Chap. XI were prepared by Prof. E. A. Holbrook; Chap. IX, X, pages 152–157 of Chap. VIII, and pages 173–177 of Chap. XI were prepared by Mr. O. S. Beyer; Chap. VIII, pages 133–152, was prepared by Mr. C. M. Hebbert.

In the Chapter on "History of Aviation" only those experiments are treated which have a bearing on flight today; this chapter is to be used in conjunction with the Chapter on "Principles of Flight," especially as regards controlling the airplane.

The question of Airplane Motors has not been touched, because to do it justice would unduly increase the size of this volume, and because adequate treatises on the subject are available.

Dec. 12th, 1917.

CONTENTS

LEARNING TO FLY
IN THE
U. S. ARMY

A MANUAL OF AVIATION PRACTICE

CHAPTER I

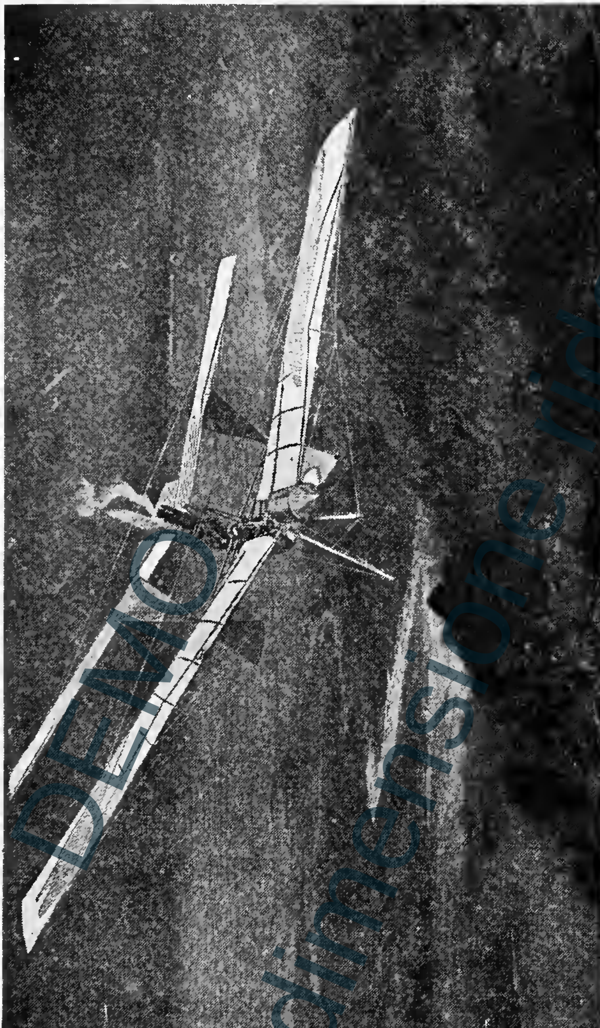
HISTORY OF AVIATION

That part of the history of Aviation which has especial interest for aviators is of recent date, and extends back only two dozen years. Of course efforts have been made toward manflight ever since the early sixteenth century, when Leonardo da Vinci invented the parachute and became the first patron of aeronautics; between the time of this famous artist and the present many experimenters have given their attention to the problem, but previous to the last decade of the nineteenth century nothing practical was achieved. Then, with the perfection of the steam engine and the development of the gasoline engine, there came inducement to sound experimentation, bringing forth such well-known figures as Maxim, Langley, Lillienthal and Chanute.

The work of each of these men is an interesting story by itself, especially that of Langley, who approached the matter from a strictly scientific viewpoint, established testing apparatus and built successful self-propelled steam models years before the Wright brothers reported their independent successes. He reproduced his models to full scale with every expectation of success, but failed, due to exhaustion of his capital.

Langley's Experiments in Aerial Navigation.—In all the history of aerial navigation one of the most romantic stories is that describing the scientific researches begun in 1887 by Langley and culminating in 1896 in the first really successful case of mechanical flight using a prime mover; continuing up to 1903 when this first successful machine, a model of 12-ft. span, was reproduced to full scale and manned for its trial flight by a human pilot; and ending with the destruction of this full-sized machine on launching, so that Langley missed the glory of being the actual discoverer of manflight only by a hair's breadth, dying shortly afterward of a broken heart, as is conceded by those who knew him. If this full-scale machine had performed as successfully in 1903 as it actually did after being rebuilt and partly remodelled a decade later by the Curtiss company, Langley would have antedated the first successful flight made by the Wright brothers by a narrow margin of about 2 months.

Lillienthal (**Germany, 1894**).—But omitting details regarding the early experimenters we will consider only that part of the history of aviation most important to the prospective aviator. We will confine ourselves to the sequence of gliding and



(*Courtesy S. S. McClure Co.*)

FIG. 1.—The Langley steam model flying machine.

It flew a mile in 1896, the first successful airplane to fly with a prime mover.

power experiments begun by Lillienthal, carried forward by Chanute and brought to completion by the Wrights.

Lillienthal was the first man to accomplish successful flights through the air by the use of artificial

(*Courtesy Jas. Means' "Aeronautical Annual."*)

Fig. 2.—Lillienthal's biplane glider in flight, 1894.

Note.—(*a*) Arched wings; (*b*) fixed tail; (*c*) method of balancing by swinging legs

wing surfaces. After many years of experiment and study of soaring birds he constructed rigid wings which he held to his shoulders and which, after he had gained considerable velocity by running forward downhill, would catch the air and lift his weight completely off the ground. The wings were arched, for he observed this was the case in all birds; flat wings proved useless in flight, and suggested a reason for the failure of previous experi-

(*Courtesy Jas. Means' "Aeronautical Annual."*)
FIG. 3.—Chanute's biplane glider, 1896.
Note improvement in rigidity by bridge-type trussing.

menters. To these rigid wings Lillienthal fastened a rigid tail; the wings and the tail comprised his "glider." There were no control levers and the only way the operator could steer was to shift the balance by swinging his legs one way or the other.

Lillienthal constructed an artificial hill for his gliding so that he could coast downward for some distance without striking the ground and he was able to accomplish many glides of a couple of hundred yards in length.

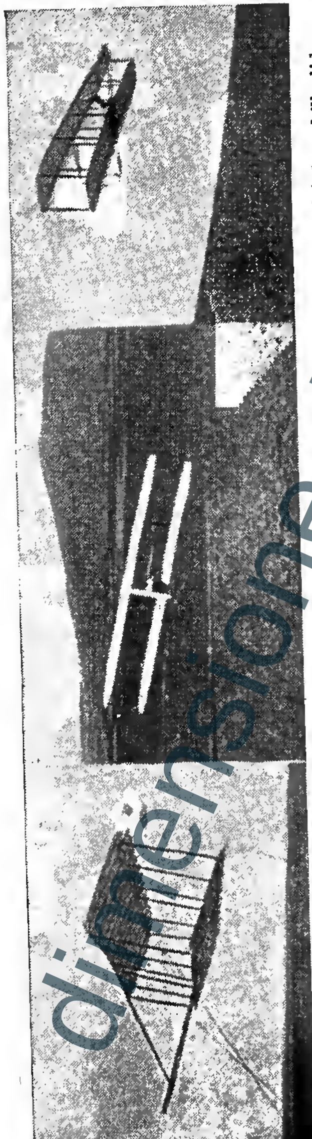
Chanute (Chicago, 1896).—Chanute's experiments in gliding were quite similar to Lillienthal's and were made on the sand dunes along Lake Michigan outside of Chicago. His apparatus was more strongly constructed, being of trussed biplane type, a construction suggested to him by his experience in bridge building, and one which persists today as the basis of strength in our present military biplanes.

The Wright Brothers, 1901.—Lillienthal was killed in a glide, having lost control of his apparatus while some distance above the ground. The Wright brothers read of his death and commenced thinking over the whole problem. Lillienthal's method of balancing his large apparatus by the mere effect of swinging his legs appeared to them as a very inadequate means of control. They came to the conclusion that the immediate problem in artificial flight was the problem of stability, which they felt should be solved by an entirely different means than that employed by Lillienthal and Chanute. The work already done had demonstrated without question that support in the air had been established; with the addition of controllability the Wrights looked forward to doing something worth while in the way of artificial flight.

To improve Lillienthal's method of shifting the weight, they conceived the idea of leaving the pilot in an immovable position in the glider, and instead of obliging him to shift his weight this way and that, they proposed to manipulate the surfaces of the wings themselves by means of levers under the pilot's control, so that the same result of balancing could be obtained by quite a different and superior method.

They set out, therefore, deliberately to solve the whole question of airplane stability. There was the fore and aft or horizontal stability, for which Lillienthal had swung his legs forward and backward; there was in addition the sidewise or lateral stability for which Lillienthal had swung his legs to left and right. The fundamental requirements to be met were that during flight the glider should be kept in its proper attitude without diving or rearing up, and without rolling into an attitude where one wing tip was higher than the other, *i.e.*, the machine was to be kept level in both directions.

Fore and Aft Control.—After some preliminary trials the Wrights found that the fore and aft balance could be controlled by an elevator or horizontal rudder, supported on outriggers on the front of the airplane, and operated by a lever. If the pilot found the glider pitching too much downward, and tending toward a dive, he would tilt the elevator upward by moving the lever, thus turning the glider back into its proper attitude. This elevator in modern machines is back of the airplane,



First Wright glider.
With front elevator, shown flying empty as a kite.

Final Wright glider.
With rudder and elevator. Note right wing warped downward to raise right wing tip.

A successful downhill glide.
Pilot lies prone on bottom wing.

Fig. 4.

a better place for it than was chosen by the Wrights. It may be said that their chief reason for first putting it in front was that they could see it there and observe its effect. They soon realized that the rear location gave easier control, and they acted accordingly.

Lateral Control.—After satisfying themselves regarding fore and aft control, the Wrights took up lateral control. Their problem was to devise a means for keeping the span of the wings level so that when for any reason one wing tip should sink lower than the other, it could be at once raised back to its proper position. Lillienthal had tried to do this by swinging his legs toward the high side; the shifted weight restoring the position. The Wrights, to obviate this inadequate method, bethought themselves to restore equilibrium by means of the wind itself rather than by gravity. They observed an interesting maneuver employed by a pigeon which seemed to secure its lateral balance in exactly the way they wanted; this bird was seen to give its two wings each a different angle of attack, whereat one wing would lift more forcibly than the other, thereby rotating the bird bodily in any desired amount or direction about the line of flight as an axis. To copy this bird apparatus in a Wright glider, it was found sufficient to alter the angle of the wing tips only, leaving the chief part of the supporting surface in its original rigid position. In other words, the wing tips were to be warped; the one to present greater angle of attack, the other less angle, exactly as in the case of the pigeon. Suppose the airplane to develop a list to the left, the wing on that side sinking, the pilot was to increase the angle at the tip of this left-hand wing by moving the warping lever, and at the same time decrease the angle of the right-hand wing by the same lever. He was to hold this position until the airplane was righted and brought back to level position.

This arrangement proved to have the effect anticipated and maintained stability easily on a glider much larger than Lillienthal ever managed with his leg-swinging method.

Directional Control.—We have now followed the development by the Wrights of airplane control as regards:

1. Fore and aft or "pitching" motion, accomplished by an elevator operated by lever.

2. Lateral or "rolling" motion accomplished by wing warping operated by a second lever.

These were the only controls used in the earliest gliders. It remains to consider the third element of control, viz:

3. The directional or "yawing" control, which is accomplished by an ordinary vertical rudder operated by a third lever.

The Wrights found the warping had all the effect anticipated but had also certain secondary and undesirable effects. Whenever they applied the warping lever to correct the rolling motion, the glider responded as far as rolling control was concerned, but at the same time would "yaw" or swerve out of its course to right or left. This was a serious complication. For, in the moment of swerving, the high wing which they desired to depress would advance faster than the low wing, and solely by its higher velocity tended to develop a greater lift and thereby neutralize the beneficial effect of the warp. In many of their early glides, because of pronounced swerving, the warp effect was entirely counteracted and failed to bring the glider back to level; with the result that one wing tip would sink, at the same time swinging backward until the machine was brought to the ground. No amount of controlling could prevent this.

After much bewilderment on this point, the Wrights observed that whenever a wing tip was warped to a large angle its resistance became relatively greater and it slowed up while the opposite side went ahead. They at once hit upon the idea of a rudder, previously considered unnecessary, which they believed could be turned in each case of yawing just enough to create a new and apposing yawing force of equal magnitude.

They therefore attached a rudder at the rear, connecting its tiller ropes to lever No. 2, and giving this lever a compound motion so that one hand could operate either warp or rudder control independently (or simultaneously in proper proportion to eliminate the yawing tendency above mentioned). This combination is the basis of the Wright patents and is essential in airplanes of today.

Great success now ensued in their gliding experiments; the machine was always in perfect control; could be manipulated in any desired manner; turned to right or left, or brought down to earth with safety.

Thus were the three elements of control applied by the Wrights to their glider and the problem apparent in Lillienthal's death was solved. The next step was to install a power plant able to maintain forward speed without resorting to coasting downhill by gravity; and therefore capable of producing a horizontal flight.

In developing a power flyer aside from the question of control the proper design was arrived at as follows:

Efficiency of Wings.—The Wrights knew from Langley and Chanute that flat wings were inefficient and useless, and curved wings essential; they did not know whether the amount of curvature mattered much. To find this out by trials in gliding would be slow and expensive. They adopted a better way—the wind-tunnel method, wherein small-scale models were tested and compared for efficiency in a blast of air. They made their wind tunnel 16 in. in diameter and created a powerful air blast through it by means of an engine-driven fan. Small models of wings were placed in the center of this confined air blast, mounted on a balance arm which projected into the tunnel from the outside. The air forces and efficiency of the models were thus measured. A large variety of shapes were tested and one was selected as best of all from the standpoint of curvature and rounded wing tips. This shape was adopted in their flyer, and though on a much larger scale fulfilled the predictions made for its efficiency in the indoor wind-tunnel experiments.

The Wright glider was, of course, a biplane model. They tested a small 6-in. model biplane and found that the two wings together were less efficient than either wing by itself. However, other considerations, such as rigidity of trussing, decided them to adopt the biplane rather than a monoplane arrangement.

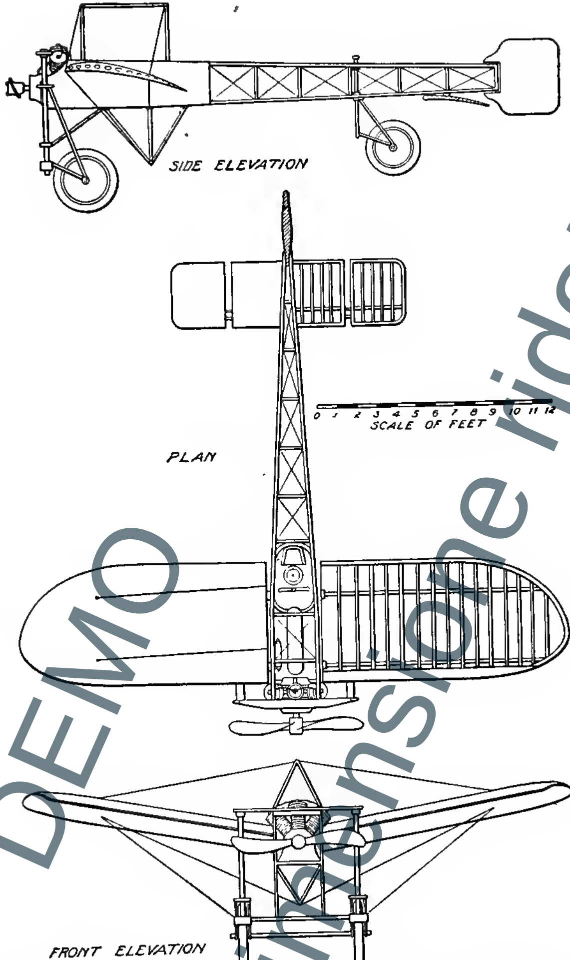
Low Resistance to Forward Motion.—The Wrights used their wind tunnel also in choosing for the struts of their airplane a shape which would present least head resistance to forward motion. They found that a square strut had a resistance which could be decreased by changing the shape to resemble a fish. The resistance of the pilot himself was decreased by making him lie prone, face downward on the bottom wing.

Propeller Efficiency.—Although little data on the subject of propeller efficiency was available to the Wrights, they were able to arrive at a very creditable design wherein two propellers were used, driven from a single motor, and rotating one each side of the pilot. The mechanical difficulties which have since embarrassed the use of two propellers were less with the Wrights because they were dealing with smaller horsepowers than are in use today; they therefore were able to realize a very high propeller efficiency.

Motor.—When the Wrights were ready to apply a motor to their glider, they found it impossible to secure one light enough, and had to set about building one themselves. They adopted a four-cylinder type, water-cooled, and their aim was to save weight and complication wherever possible. Their first motor gave about 12 hp., which was raised to a higher and higher figure by subsequent improvements until it reached 20 hp. In its earliest stages it was able to give sufficient power for short horizontal flights.

Means of Starting and Landing.—One reason the Wrights could use such low horsepower was that they employed auxiliary starting apparatus to get up original speed. They knew that less horsepower was necessary to fly an airplane after it was once in the air than was necessary to get it into the air at the start, and they therefore rigged up a catapult which projected their airplane forward on a rolling carriage with great force at the start, so that all the motor had to do was to maintain the flight in air. The Wright airplane had at first no landing wheels, and was provided only with light skids on which it could make a decent landing. Present-day airplanes, of course, have wheels on which to roll both at starting and at landing and their motors are powerful enough to eliminate the necessity for a starting catapult.

Bleriot's Contribution to Aviation.—Bleriot experimented a great many years before he attained success and did so years after the Wrights had



(Courtesy American Technical Society and Scientific American Supplement.)

FIG. 5.—Details of Bleriot XI monoplane.

successfully flown. But when he did obtain success, his great ingenuity produced features of design which were a decided step forward. He added a body to the airplane and produced a machine which instead of being a pair of wings with various appendages, was a body to which wings were attached, giving a more shipshape and convenient arrangement. The motor, instead of being located beside the pilot as in the Wright machine, was put in the very front of the body ahead of the pilot where it was not likely to fall on him in case of a smash. This location of the motor entailed the use of a single propeller at the front, a "tractor" screw as it was called, less efficient than the double propeller of the Wrights, but better from the standpoint of mechanical convenience. The body of a Bleriot, which was quite similar to the body of any bird in its general arrangement, projected to the rear in a tapering form and carried at the rear a rudder and elevator. The motor, pilot and tanks were thus enclosed within the body and away from the wind. Bleriot's contributions were then, better location of the motor, adaptation of the body or "fuselage," elimination of the front elevator and substitution of the rear elevator.

Nieuport and Fokker's Contribution to Aviation.—A further advance on Bleriot's design was made by Nieuport and later by Fokker. The former utilized the fuselage principle of Bleriot and enclosed the whole framework, front and back, to give a stream-line form, and even went so far as to tioned must be met by a strong opposite righting force, and this latter is furnished by the horizontal tail surface. In the angle of equilibrium of 2° above mentioned, the flat horizontal stabilizer will

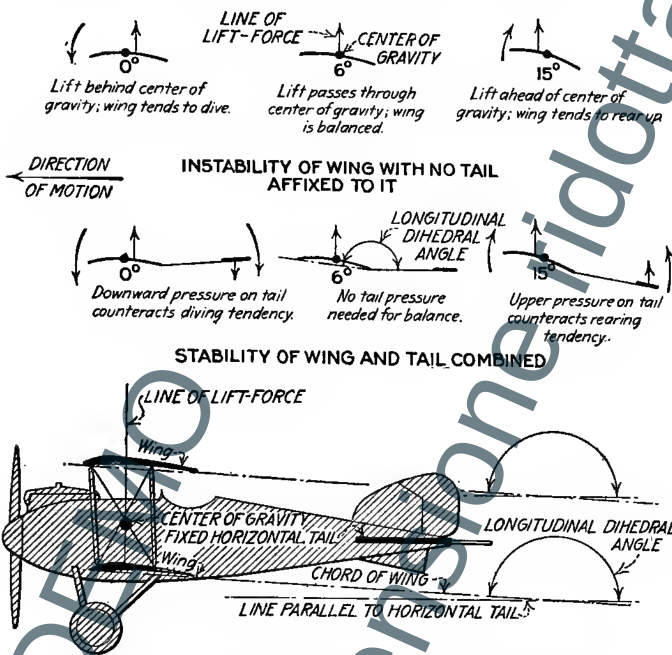


Fig. 29.—Diagrams illustrating theory and application of longitudinal dihedral angle.

perhaps have no force acting on it at all because it is edgewise to the air and its angle of incidence is zero. When the angle of the wing increases to 2¼° and the lift moves forward tending to rear it up, the wing being rigidly fastened to the body pushes the tail downward so that the tail now begins to have a small lift force upon it due to its angle of ¼°; and this newly created force, though small, acts at such a long lever arm that it exceeds the rearing force of the wing and will quickly restore the airplane to 2°. This action depends upon the principle of the Penaud Tail or longitudinal "Dihedral" which requires that the front wings of an airplane make a larger angle with the wind than the rear surface. This principle holds good even when we have rear surfaces which actually are lifting surfaces in normal flight, the requisite being that the wings themselves shall in such cases be at an even greater angle than the tail. No mention has been made of the elevator control, because its action is additional to the above-mentioned stability. The elevator is able to alter the lift on the tail; such alteration requires, of course, immediate change of angle of the wings so that equilibrium shall again follow; and this equilibrium will be maintained until the lift at the tail is again altered by some movement of the elevator control. Thus the elevator may be considered as a device for adjusting the angle of incidence of the wings.

The air through which the wings have passed receives downward motion, and therefore a tail which is poised at zero angle with the line of flight may actually receive air at an angle of −2° or −3°. In the above case we would expect an actual downward force on the tail, unless this tail is given a slight arch on its top surface (for it is known that arched surfaces have an angle of zero lift which is negative angle).

Longitudinal Control.—Steering up or down is done by the elevator, which as explained above is merely a device for adjusting the angle of incidence of the wings. The elevator controls like all the other controls of an airplane depend for their quick efficient action upon generous speed; they can not be expected to give good response when the machine is near its stalling speed. The elevators like the rudder are located directly in the blast of the propeller and in case the speed of motion should become very slow, the elevators may be made to exert considerable controlling force if the motor is opened up to blow a strong blast against them. This is good to bear in mind when taxying on the ground because if the motor is shut off at the slow speed of motion the elevator and rudder will lose their efficacy. The propeller blast, due to a 25 per cent. slip, adds 25 per cent. of apparent speed to those parts which are in its way, and therefore the tail forces are affected as the square of this increase, that is, the forces may be 50 per cent. greater with the propeller on than off.

Lateral Stability.—This depends upon the keel surface or total side area of an airplane. The keel surface includes all the struts, wires, wheels, wings, as well as body, against which a side wind can blow. Skidding and side-slipping have the same effect as a side wind, and the resulting forces acting against the side of the machine should be made useful instead of harmful. This is done by properly proportioning the keel or side surface. If keel surface is low, the side force will rotate the airplane about its axis so that the windward wing sinks; if high, so that it rises. But if the keel surface is at just the right height (*i.e.*, level with the center of gravity) the side forces will not rotate the machine at all and will simply oppose the skidding without upsetting equilibrium.

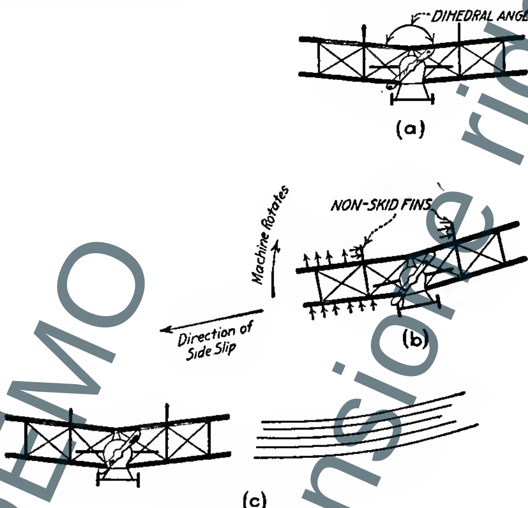


FIG. 30.—Diagram showing effect on lateral stability of dihedral angle and non-skid fins.

(*a*) Machine flying level. (*b*) Machine tips and side-slips: excess pressure is created on windward wing and fins. (*c*) Machine has side-slipped and rotated back to level.

Lateral Dihedral.—Now when an airplane appears to have its keel-surface center too low, the easiest way to raise it level with the center of gravity is to give the wings a dihedral angle, that is make them point upward and outward from the body. Thus their projection, as seen in a side view, is increased, and the effect is to add some keel surface above the center of gravity, thus raising the center of total keel surface.

A further advantage of the lateral dihedral is that any list of the airplane sideways is automatically corrected (see Fig. 30). The low wing supports better than the high wing, because a side slip sets in, hence will restore the airplane to level position.

Non-Skid-Fins.—Where for the above-mentioned purposes an excessive dihedral would be needed, resort may be had to non-skid-fins erected vertically edgewise to the line of flight above or beneath the topwing. These are used in marine machines to balance the abnormally large keel surface of the boat or pontoon below.

Lateral Control.—By means of ailerons, lateral control is maintained voluntarily by the pilot; the aileron on the low tip is given a greater angle of incidence while on the high tip a less angle of incidence thus restoring the proper level of the machine. Notice that the efficacy of the ailerons depends upon speed of motion of the airplane, irrespective of propeller slip because the propeller slip does not reach the ailerons. Therefore, at stalling speeds the ailerons may not be expected to work at their best, and when lateral balance is upset at slow speeds it is necessary to dive the machine before enough lateral control can be secured to restore the balance.

Directional Stability.—Directional stability has to do with the tendency of an airplane to swerve to the right or left of its proper course. To maintain directional stability the "vertical stabilizer" is used, which acts in a manner analogous to the feather on an arrow. Thus in case of a side slip the tail will swing and force the airplane nose around into the direction of the side slip so that the airplane tends to meet the relative side wind "nose-on" as it should. The vertical stabilizer should not be too

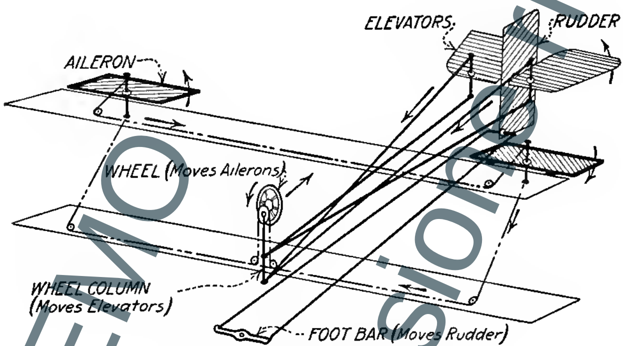


Fig. 31.—Deperdussin control.
System used in U. S. training airplanes.

large, however, as then any side pressure due to deviation from a rectilinear course will cause the machine to swerve violently; the wing which is outermost in the turn will have preponderance of lift due to its higher speed; that is, the airplane will get into a turn where there is too much bank and a spiral dive may result.

Directional Control.—The rudder gives directional control in exactly the same way that it does on a boat; it should be said, however, that the rudder is sometimes used without any intention of changing the direction, that is, it is used simultaneously with the ailerons as a means of neutralizing their swerving tendency. The ailerons, of course, at the same time that they restore lateral balance create a disadvantageous tendency to swerve the machine away from its directional course; that is what the rudder must neutralize. Moreover, the rudder is frequently used against side winds to maintain rectilinear motion.

Banking.—Banking combines the lateral and directional control, which should be operated simultaneously so as to tilt the machine and at the same time maintain the radius of turn. The wings are tilted in a bank because in going around a curve of a certain radius the weight of the machine creates a centrifugal force in a horizontal direction and if the curved path is to be maintained this centrifugal force must be neutralized; and this is done by inclining the force of lift inward until it has a horizontal component equal to the centrifugal force. That is why the angle of bank must be rigidly observed, or else the inward component of the lift will change. Now as soon as the wings bank up, the lift force is no longer all vertical and therefore may not be enough to support the weight of the machine. To offset this have plenty of motor power for speed in a bank; and do not try to climb while banking.

It is better to bank too little than too much; too little results in skidding which may be easily cured; too much results in side slipping inward and if the tail surface is too great in this latter case, a spiral dive may result—so look out for overbanking.

It is better for the beginner in banking to move his ailerons first and then move the rudder; for if he moves the rudder first there will be skidding outward, forward speed will drop and a stall may result. On high angles of banking, over 45°, it should be noted that the elevators are now more nearly vertical than horizontal and operate as a rudder; similarly the rudder's function is reversed, and to turn down the rudder will be used.

Damping in an Airplane.—Above have been mentioned the restoring forces which tend toward airplane equilibrium. Now these restoring forces tend to push the machine back to equilibrium and even beyond in exactly the same way that gravity causes a pendulum to swing about its point of equilibrium. This can sometimes be noticed in the case of an automobile when travelling at high speed along country roads where a sort of slow oscillation from side to side may be noticed due to the forceful maintenance of equilibrium of the body in its forward motion. This oscillation in an airplane would be serious unless there were means of damping it out and these means are: first, the wings; second, the tail surfaces; third, the weight and inertia of the machine itself. Regarding inertia it should be said that a machine with weight distributed far from the center of gravity, such as the double-motor airplane has a large tendency to resist the rolling motions associated with lateral stability. But from the same sign airplanes with large moment of inertia are difficult to deviate from any given attitude, and therefore have the name of being "logy." The proper proportioning of an airplane's parts to secure first, the restoring forces; second, the proper damping force; third, the proper amount of moment of inertia, is a very delicate matter and beyond the scope of the present chapter.

CHAPTER IV

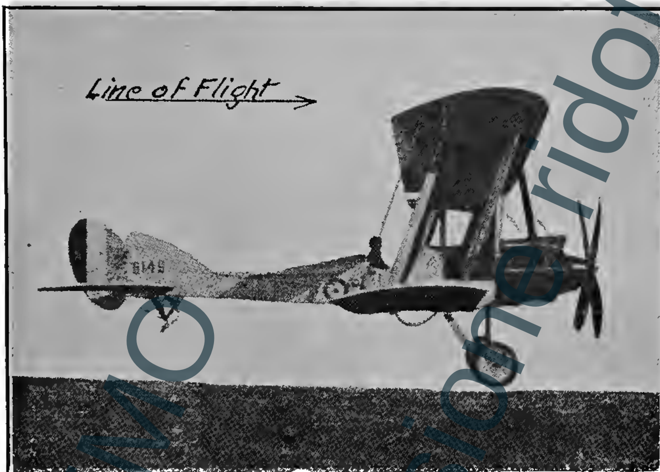
FLYING THE AIRPLANE

Starting Off.—The first thing to do before starting off in an airplane is to inspect carefully everything about the machine and assure yourself that it is in perfect condition.

When all is ready to start turn the machine directly against the wind; this is done in order that the rise from the ground may be more quickly made with the assistance of the wind under the wings, and it has a more important advantage in the fact that if you try to get off the ground across the wind the machine will be very hard to balance. Birds also take the air directly against the wind even though for the moment this carries them in a direction toward some supposed enemy, and it is a fundamental principle in airdromes. Keep the machine pointed into the wind for the first 200 ft. of altitude (and similarly in landing face the wind when within 200 feet of the ground). In case the engine should fail before a height of 200 ft. is reached, never turn down wind as this is extremely dangerous.

Assistance will be had for the start from the mechanics, or if away from the airdrome from bystanders. Have each assistant in his proper place before starting the engine; one is to start the propeller and the rest to hold back the machine until ready to let go.

In order to get off the ground you will want good engine power; it takes considerable thrust to



(From "How to Instruct in Flying.")

FIG. 32.—Airplane in flying position just after starting. This cut also illustrates proper landing attitude, since airplane is just skimming the ground.

accelerate an airplane on the ground to its flying speed; in fact the first flying machine of the Wrights had to use an auxiliary catapult to furnish the thrust necessary to get them into the air. Making sure that the motor is giving full power raise the hand as a signal to the attendants to remove the chocks and let go. As you start rolling forward push the control lever forward which will raise the tail off the ground and place the wings edgewise to the wind while they will not offer resistance to the acquiring of good rolling speed. Within a few seconds the machine will have attained on the ground a velocity not less than the low flying speed; it will not rise, however, until the tail is lowered by pulling the lever back. When the necessary rolling speed is attained pull the lever softly backward; the tail at once drops, the wings increase their angle and lift and the machine will rise, the lever being held in a fixed position (see Fig. 32). The distance between the point of starting and rising will be 100 yd. or more and will occupy from 5 to 10 sec. depending on the wind.

The change from flying position to climbing position is only a slight modification involving only a slight pulling back of the control lever and holding it in fixed position; the motor may in some machines simply be opened out when its increased power will make the machine rise; however, there is only one speed at which the climb will be fastest and therefore it is well to know what is the proper speed for climbing; the motor is then opened out full and the airplane operated to give the proper speed corresponding.

The pupil should rise to the height of at least 100 ft., as any less is useless and nothing will be learned from landing. In the case of cross-country flying the pilot will rise to the height of 2000 ft., circling over the field rather than flying off in a straight ine so that preparatory to his start he always has the flying field in reach.

Landing.—Proper landing is the most important thing in airplane flying. The pilot in turning his machine downward toward a landing spot from flight will choose a distance from the field equivalent

(From "How to Instruct in Flying.")

FIG. 33.—Airplane in gliding position, approaching a landing. Note that its attitude relative to line of flight is similar to "flying position," line of flight however being inclined.

to the proper gliding angle of his machine. If the gliding angle is 1 in 7 he must not turn downward any further from the field than a distance greater than seven times his altitude or he will fall short. It is safer to come closer to the field before turning downward for two reasons: first, because you may not be gliding at the best gliding angle; second, because you can always kill extra height by a spiral or two better than you can regain it. Have height to spare when landing.

To come down throttle down the engine and push the lever softly forward until the proper gliding angle is obtained (Fig. 33). The reason for throttling down the engine is: first, that you do not need its thrust when you are coasting down because gravity furnishes all the necessary velocity; second, if you glide or dive with the motor wide open high speed will result, resulting in strains on the machine especially on the moment of leveling out again; third, at this high speed the controls become stiff to operate.

Maintain the proper gliding speed to within 5 miles an hour of what it ought to be as it is the speed which determines the proper gliding angle. The revolution counter will indicate what the speed is or the air-speed meter may be used. Arrange to come on to the field facing directly into the wind, which may be observed by watching smoke or flags below. In landing against the wind you are again copying the practice of the birds. When you come to within 15 ft. of the ground pull the lever softly back until the machine is in its slow-flying position, which should be attained 5 ft. above the ground (Fig. 34). Hold the stick at this position of horizontal flying; no further movement of the lever is necessary except to correct bumps, for which purpose it would be held lightly for instant action.

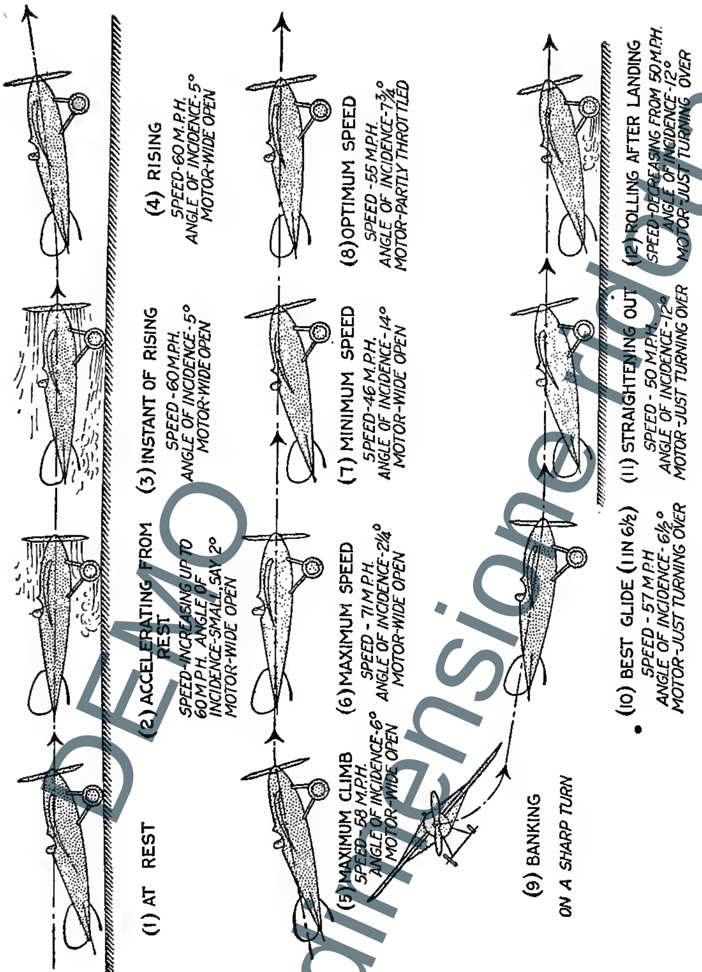


Fig. 34.—Attitudes of an airplane in flight.

The aileron control must be used here to keep the machine level and it may be necessary to operate the rudder after touching the ground in order to avoid swerving; in fact some machines are provided with a rear skid which steers for this purpose.

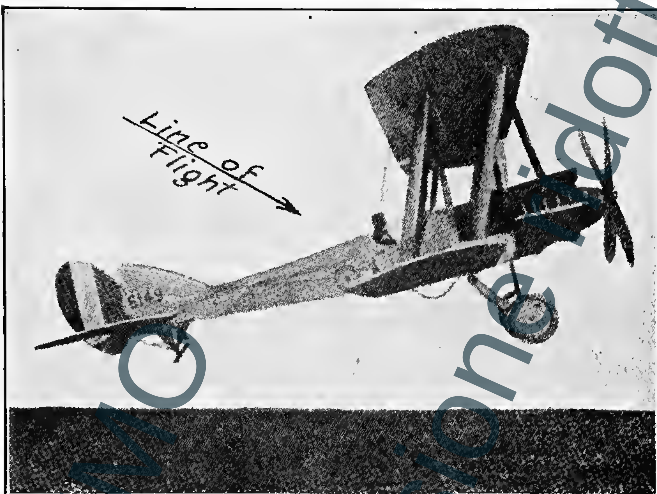
In rolling just after landing keep the tail as close to the ground as possible without causing undue bumping, so that the maximum resistance of the wings may be presented to the air and the machine be slowed up rapidly. Some machines are fitted with brakes on the wheels to assist in the quick retardation of the roll. Landing is one of the biggest problems in aviation and is a hard thing to learn because it is done at a high speed especially in the fast military machines such as the Fokker, Nieuport, etc. Landing is more of a problem than it used to be in the early days when, for instance, the Wrights were able to land without any wheels at all on mere skids because their machines were not fast.

The following are examples of bad landings:

1. The pancake results from allowing the machine to get into its rising position when it is landing (Fig. 35). There will be a perpendicular bounce and on the second bounce the running gear will break. In order to get out of an immanent pancake open up the engine to keep machine flying, put the machine into a flying position, then throttle down again and land.

2. Another type of pancake results from bringing the machine out of its gliding position at a point

too far above the ground when the machine will drop due to lack of speed and break the running gear. To avoid this open motor full, thus regaining speed and flying position; afterward throttle down and reland.



(*From "How to Instruct in Flying."*)

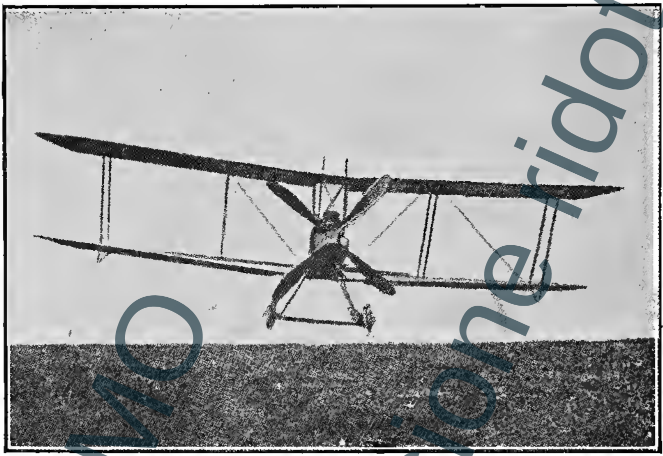
FIG. 35.—Bad landing, Type 1—the "pancake" landing.

Line of flight is downward; angle of incidence large, hence speed is slow; but there is too much downward momentum and landing gear will break. Should line of flight arrow point upward, airplane as shown would then be in climbing position.

3. A third type of bad landing results from failure to turn the machine out of its glide at all, so that it glides straight downward until it touches the ground. This is the most dangerous case of all the bad landings. To cure it open up the engine after the first

bounce, regaining flying speed before the second bounce; then reland.

4. If at the moment of landing the rudder is turned causing machine to swerve, or if the machine is not level, a side strain will be placed upon the landing gear and the wheels will buckle (Fig. 36).



(*From "How to Instruct in Flying."*)

Fig. 36.—Bad landing Type 4—machine not level. Wheels do not touch ground at same time, and one may smash.

Are holes drilled properly. Do fittings fit?

Sheet aluminum should be inspected for defects such as cracks, bad dents, etc. Where openings occur in sheet aluminum the corners should be rounded, allowing a good-sized radius.

Directions for Work.

Before you start work on rigging you are advised as follows:

1. Do not hurry about the work. No rush jobs can be done in airplane rigging.

2. You are cautioned against leaving tools of any kind in any part of the airplane.

3. The bolts and their threads must not be burred in any way; for this reason, the use of pliers or pipe wrenches on bolts is very bad form.

4. Start all turnbuckles from both ends every time they are connected up.

5. Full threads must be had in every case to develop the full strength of a bolt and nut, with turnbuckles at least turn on for a distance equal to three times the thickness of the shank.

6. Lock with safety wires all turnbuckles and pins, and cotter-pin every nut.

7. Watch for kinking of wires and their rubbing around controls and wherever they may vibrate against one another.

8. All bolts and pins must have an easy tapping fit only; do not pound them into position.