Winnipeg Headingley Aero Modellers

Things About Airplanes ….

Table of Contents

List of Figures

Introduction

"Things About Airplanes …." is intended to provide:

a. reference material relevant to the understanding of how an airplane flies, useful to qualified pilots and student pilots alike, and,

b. guidance material for both instructor pilots and student pilots, useful in the conduct of flying training exercises.

The Airplane

An airplane can be defined as a "power-driven heavier-than-air craft which derives it's lift in flight from aerodynamic reactions on surfaces that remain fixed under given conditions of flight". This definition is applicable to all airplanes, regardless of scale or size.

The essential components of an airplane are:

a. the fuselage or body – the structural body to which the wings, tail section, engine and landing gear are attached,

b. the wing – the main part of an airplane, designed to create the lifting force necessary for flight. It is also the part to which ailerons and flaps, and sometimes the landing gear, are attached,

c. the tail section or empennage – the rear portion of the airplane consisting of:
   - the fixed vertical stabilizer or fin, to provide **directional stability**
   - the rudder hinged to the fin, to provide **directional control**
   - the fixed horizontal stabilizer or tail plane, to provide **longitudinal stability**
   - the elevators hinged to the tailplane, to provide **longitudinal control**

d. the propulsion system – generally a fuel powered, air cooled, internal combustion engine, which drives a 2 or 3 bladed propeller. Technology improvements now enable electric motors and scale jet engines to be used to power model airplanes, and,

e. the landing gear or undercarriage – consisting of wheels, axles and attaching mechanisms, designed to take the shock of landing and also to support the airplane and enable it to maneuver on the ground.

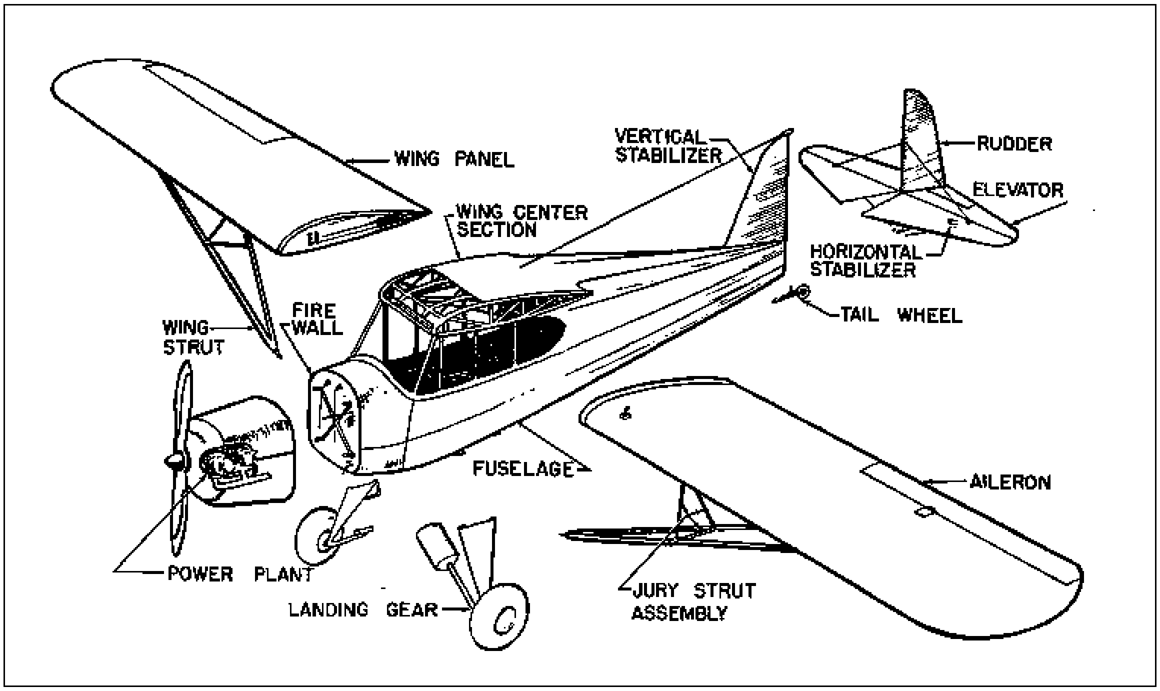

Figure 1 The Parts of an Airplane

How the Airplane is Controlled

The essential elements of a radio system used to control model airplanes are:

a. the transmitter – used to encode control stick movements by the pilot and send them to the airborne receiver in the airplane,

b. the airborne receiver – used to receive and decode the radio signals from the transmitter, convert them to electrical impulses and distribute them to the appropriate servos,

c. the servos – used to convert the electrical impulses to mechanical movement of the airplane's aerodynamic and ancillary controls,

d. the receiver battery – used to provide power to both the receiver and all of the control servos, and,

e. the electrical harness – used to link together all of the airborne components and to provide a “master switch” to activate/deactivate the airborne system.

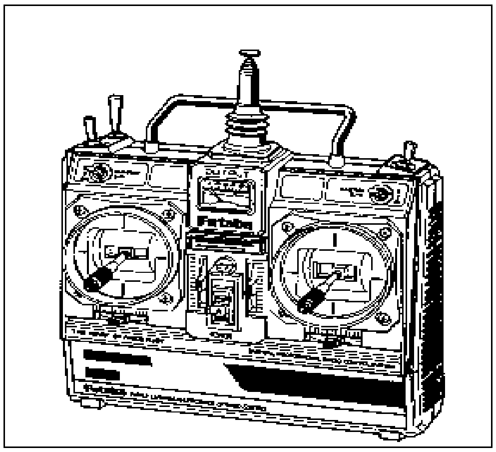

Figure 2 The Transmitter

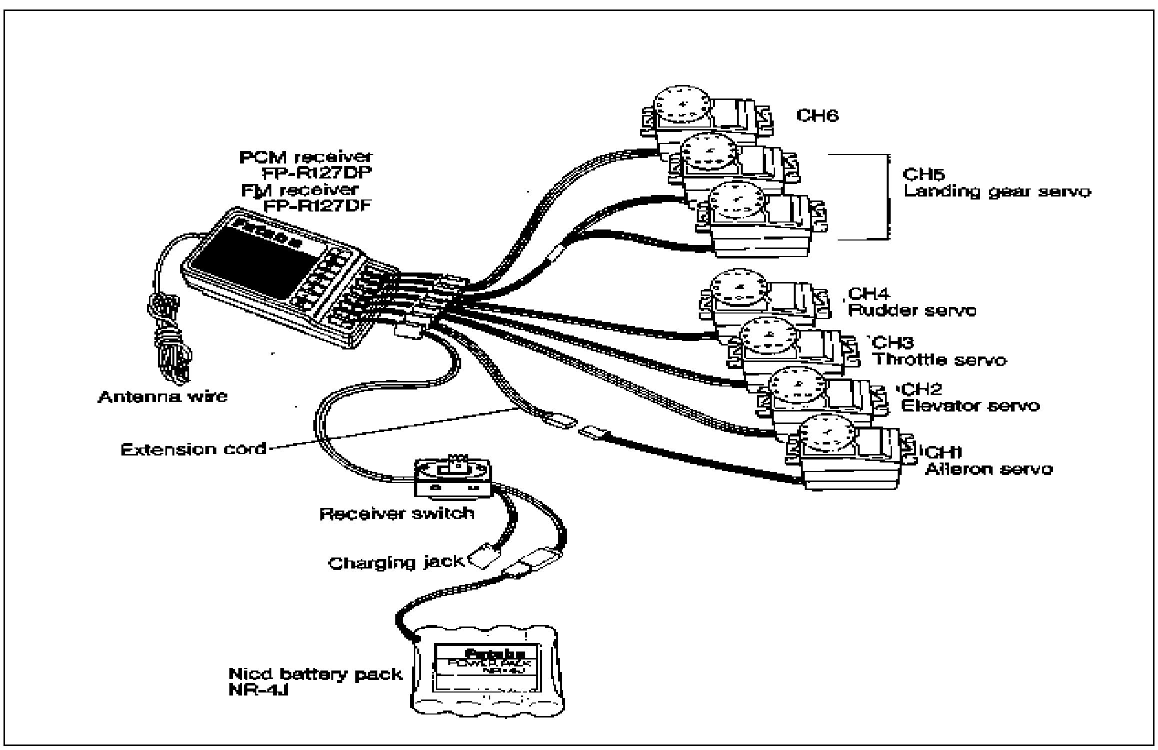

Figure 3 The Airborne Components of a Radio Control System

In a full scale airplane the pilot moves the airplane's controls with his arms, hands and legs. The radio system can be considered as an electronic extension of the pilot's arms, hands and legs. It enables the pilot to command specific movements of the airplane's aerodynamic and ancillary controls from the ground. The pilot inputs a desired control movement to the radio transmitter using the control sticks mounted on the face of the transmitter The electronic signal generated by the transmitter is received by the airborne system and is ultimately converted to a force being exerted upon the appropriate airplane control. The control will move proportionally to the amount of movement input at the control stick on the transmitter.

The **ailerons** are control surfaces hinged to the trailing edge of the wing near each wingtip and are employed to roll or **bank** the airplane. They move in opposite directions to each other and are controlled by the **Left – Right** movement of the **Right Hand** control stick on the transmitter. When the control stick is moved to the Left, the Left aileron moves Up and the Right aileron moves Down, causing the lift of the Left wing to decrease and the lift of the Right wing to increase. The Left wing descends and the Right wing rises, rolling the airplane to the Left. The airplane will continue to roll to the left, steepening the angle of bank, until the control input is neutralized, establishing a particular angle of bank. The opposite movement of the airplane is achieved by moving the control stick to the Right.

The **elevators** are control surfaces hinged to the trailing edge of the tailplane and are employed to **pitch** the airplane. They move in unison (they are normally mechanically linked together and move as a single surface). They are controlled by the **Fore - Aft** or up - down movement of the **Right Hand** control stick on the transmitter. When the control stick is moved Forward or Up, the elevators are moved Down, causing the lift of the tailplane to increase, pitching the airplane Nose Down. This movement of the airplane will continue until the control input is neutralized, establishing a particular Nose Down attitude. The opposite movement of the airplane is achieved by moving the control stick in the Aft or Down direction.

The **rudder** is the control surface hinged to the trailing edge of the fin and is employed to **yaw** the airplane. It is controlled by the **Left – Right** movement of the **Left Hand** control stick on the transmitter. When the stick is moved Left, the rudder moves to the Left, causing the lift of the fin to increase to the Right, yawing the nose of the airplane to the Left. The movement of the airplane will continue until the control input is neutralized, establishing a particular angle of yaw to the Left. The opposite movement of the airplane is achieved by moving the control stick to the Right.

The **throttle** is mounted in the carburetor of the engine and is employed to vary the power output of the engine. It is controlled by the **Fore – Aft** or Up –

Down movement of the **Left Hand** control stick on the transmitter. When the stick is moved Forward or Up, the throttle is opened in the carburettor, causing an increase in power output and rpm of the engine, stabilizing at a power setting proportional to the stick position selected on the transmitter. When the stick is moved Aft or Down, the throttle is closed in the carburettor, causing a decrease in power output and rpm of the engine.

Associated with all of the controls are companion trim switches which enable the pilot to make small adjustments to each control, independent of control stick movement.

How the Airplane Flies

There are 4 forces acting on an airplane in flight, resulting from reactions to the airstream moving over the airplane and gravity. These forces are Lift, Weight, Thrust and Drag.

Lift

This is the upward force, created by the wings, which sustains the airplane in flight.

The wings create lift due to their shape. When a vertical, chordwise section of a wing is viewed, it is seen that the upper and lower surfaces are curved and the leading edge is blunt relative to the trailing edge, somewhat like a teardrop. This section is known as the airfoil section. The upper surface of the airfoil section has a greater curvature, or camber, than the lower surface.

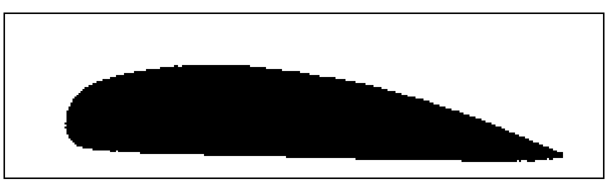

Figure 4 The Airfoil Section

The behavior of air as it moves around an airfoil can be described and explained using a variety of Laws of Fluid Dynamics and Newton's Laws of Motion. Essentially, the airfoil forces the airstream to alter its direction, which causes local changes in air pressure and velocity. The result is the creation of a net upwards or vertical force, known as lift.

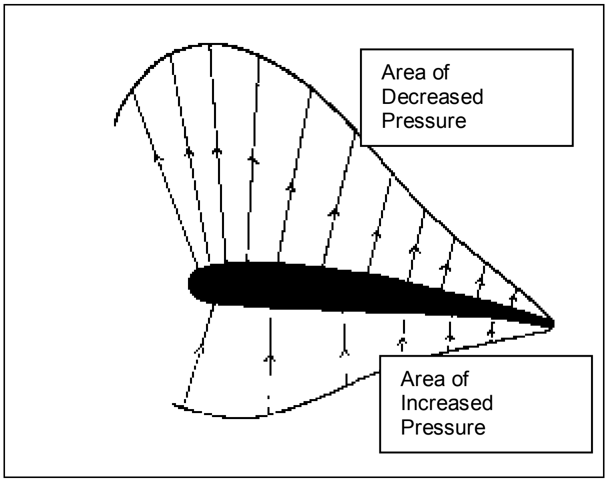

Figure 5 Changes in Pressure Distribution

Relative Wind is a term used to describe the direction of the airflow with respect to the wing. If a wing is moving forward horizontally, the relative wind moves backward horizontally Relative wind is always parallel with, and directly opposite to, the airplane's flight path.

The **Angle of Attack** is the angle at which the wing meets the relative wind.

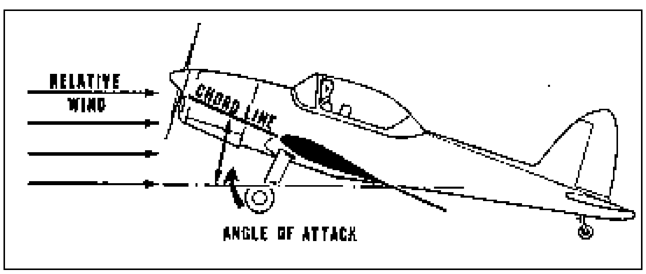

Figure 6   Angle of Attack

As the angle of attack is increased, the changes in pressure over the upper and lower surfaces intensify, causing a proportional increase in lift. The increase continues up to a certain point, called the angle of stall. Increasing the angle of attack beyond the stall angle results in a lessening of the changes in pressure, causing a decrease in lift.

If all of the distributed pressures acting on an airfoil can be considered equivalent to a single force, this force will act through a straight line. The point where this line cuts the chord of the airfoil is called the Center of Pressure. It can be seen that as the angle of attack of the airfoil is increased up to the point of stall, the Center of Pressure will move forward. Beyond that point, it will move aft.

This is a desirable feature for, as the wing stalls and loses lift, the aft-moving Center of Pressure tends to pitch the nose of the airplane down, thereby decreasing the angle of attack of the wing and regaining lift.

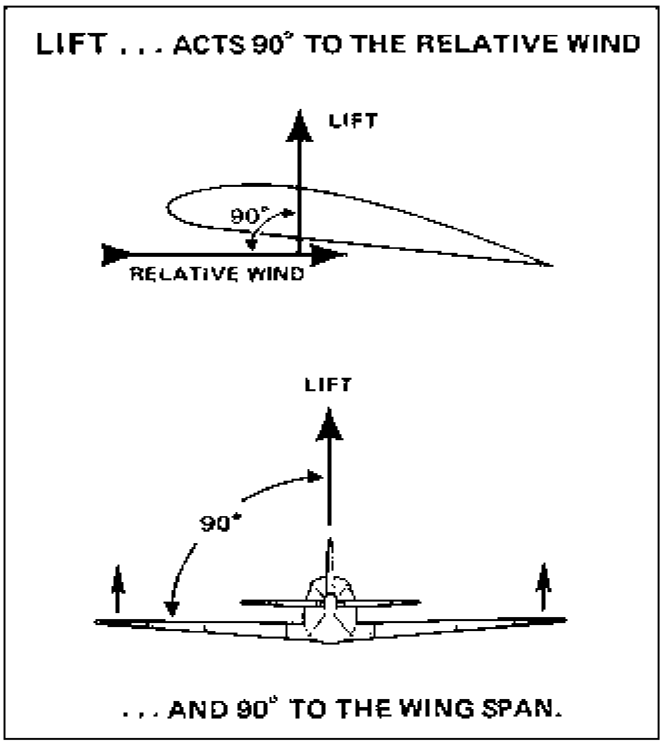

Figure 7 Lift

Weight

The weight of an airplane is the force which acts vertically downward toward the center of the earth and is the result of gravity.

Just as the lift of an airplane acts through the Center of Pressure, the weight of an airplane acts through the Center of Gravity. This is the point through which the resultant of the weights of all the various parts of the airplane passes, in every attitude it can assume.

Thrust

Thrust provides the forward motion of the airplane. There are several ways to produce this force – jets, propellers or rockets – but they all depend upon the principle of pushing a mass of air backward in order to cause a reaction, or thrust, in the forward direction.

Thrust is considered to act along the longitudinal centerline of the engine producing the thrust.

Drag

Drag is the resistance an airplane experiences when moving forward through the air.

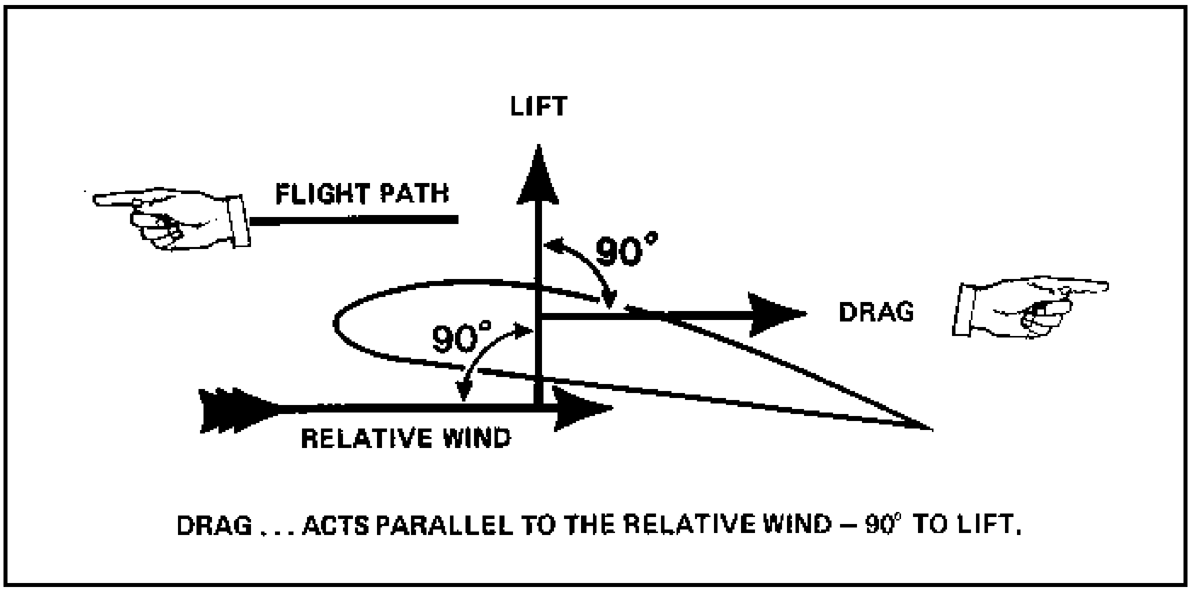

Figure 8 Drag

Drag basically consists of two types:

a. Parasite Drag – the drag of all those parts of the airplane which do not contribute to the creation of lift; that is, the fuselage, landing gear, struts, antennae, external tanks, etc. In addition, any loss of momentum of the airstream caused by openings, such as those in cowlings and between the wing and the ailerons and flaps, add to parasite drag, and,

b. Induced Drag – the drag caused during the creation of lift. It is a result of the wing's work in creating lift and is, therefore, a component of lift and can not be eliminated. It is directly proportional to the amount of lift being created.

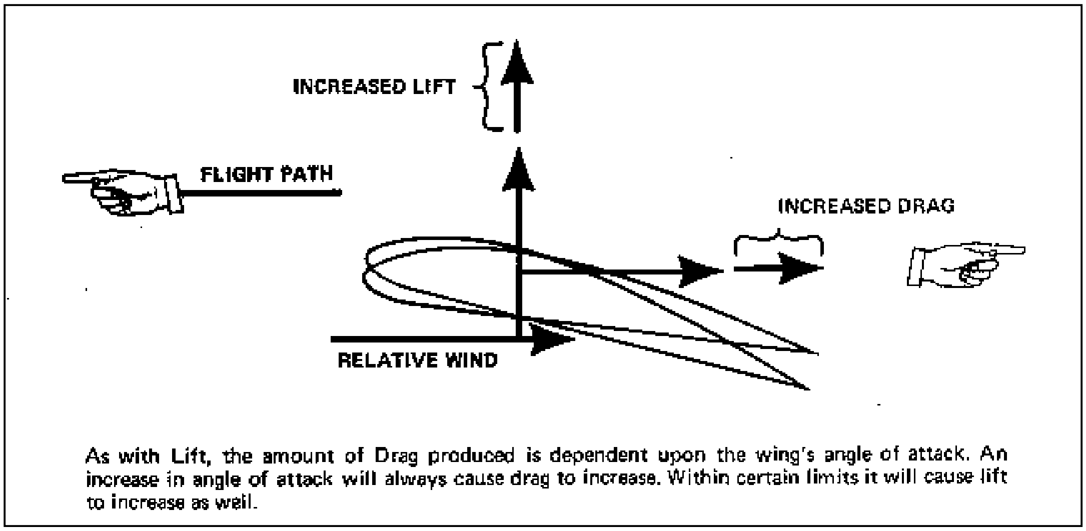

Figure 9 Increased Lift …. Increased Drag

If all of the distributed elements of drag acting on an airplane can be considered equivalent to a single force, this force will act through a straight line, parallel and opposite to the force of thrust.

Equilibrium

When thrust and drag are equal and opposite, and lift and weight are equal and opposite, the airplane is said to be in a state of equilibrium. That is, it will continue to move forward at the same uniform rate or speed. (Equilibrium refers to steady motion and not a state of rest.) If either of these forces become greater than the force opposing it, the state of equilibrium will be lost and the airplane's motion will change.

If thrust becomes greater than drag, the airplane will accelerate or gain speed. If drag becomes greater than thrust, the airplane will decelerate or lose speed.

If lift becomes greater than weight, the airplane will rise or climb. If weight becomes greater than lift, the airplane will sink or descend.

The Axes of the Airplane

There are three axes around which the airplane moves. These axes all pass through the airplane's Center of Gravity, and are named **Longitudinal, Lateral and Vertical.**

Longitudinal Axis

The **Longitudinal Axis** extends lengthwise through the fuselage from the nose to the tail. Movement of the airplane about the longitudinal axis is known as **Roll**, and is produced and controlled by the **Ailerons**. Using the ailerons, the airplane is rolled to particular **Banked Attitudes**.

Lateral Axis

The **Lateral Axis** extends crosswise from wingtip to wingtip. Movement of the airplane about the lateral axis is know as **Pitch**, and is produced and controlled by the **Elevators**. Using the elevators, the airplane is pitched to particular **Nose Up or Nose Down Attitudes.**

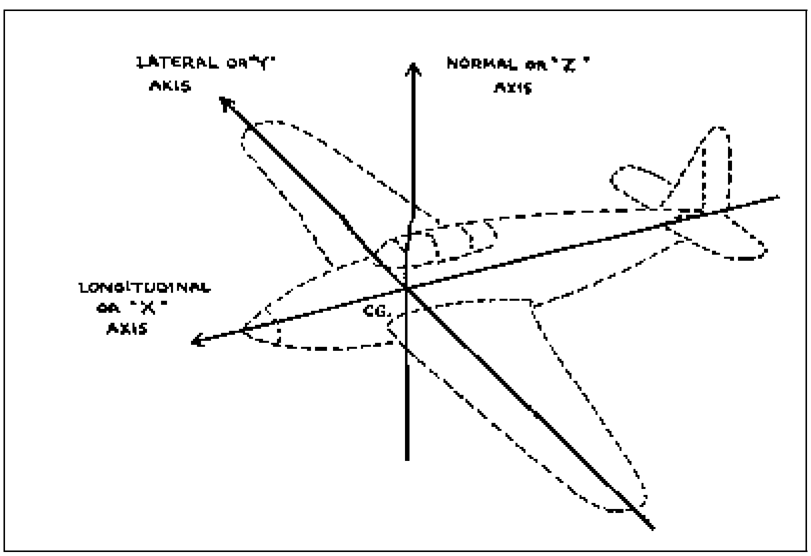

Figure 10 The Axes of the Airplane

Vertical Axis

The **Vertical Axis** passes vertically through the Center of Gravity. Movement about the vertical axis is known as **Yaw**, and is controlled by the **Rudder**.

There is a distinct relationship between movement about the vertical and longitudinal axes (yaw and roll) of an airplane. Using rudder to produce yaw will also produce roll as the wing on the outside of the turning movement will produce greater lift due to the higher relative airspeed and angle of attack. Using ailerons to produce roll will also produce a yawing motion opposite to the intended direction of turn. Known as adverse yaw, it is the result of the increased drag of the aileron on the up-going wing.

Stability

Stability is the tendency of an airplane in flight to remain in straight, level, upright flight and to return to this condition, if displaced, without corrective action by the pilot.

Stability may be **Longitudinal, Lateral, or Directional**, depending on whether the disturbance has affected the airplane in the Pitching, Rolling or Yawing plane.

Longitudinal Stability

Longitudinal Stability is **Pitch Stability** or stability about the Lateral Axis of the airplane.

To obtain longitudinal stability, airplanes are designed to be nose-heavy when correctly loaded. The Center of Gravity is forward of the Center of Pressure. This design feature is used so that, in event of engine failure, the airplane will tend to assume a normal gliding attitude. It is because of the nose-heavy characteristic that the airplane uses a tailplane to resist the diving tendency. In level, trimmed flight, the nose-heavy tendency and the negative lift of the tailplane exactly balance each other.

The longitudinal position of the Center of Gravity is very important in achieving longitudinal stability. If the airplane is loaded so that the Center of Gravity is too far aft, the inherent stability of the airplane will be lost. Even though down elevator may correct the situation, control of the airplane in the longitudinal plane will be difficult and perhaps, in extreme cases, impossible.

Lateral Stability

Lateral Stability is **Roll Stability**, or stability about the Longitudinal Axis of the airplane.

Lateral stability is achieved principally through the use of Dihedral, the term used to describe the angle each wing makes with the horizontal. If a

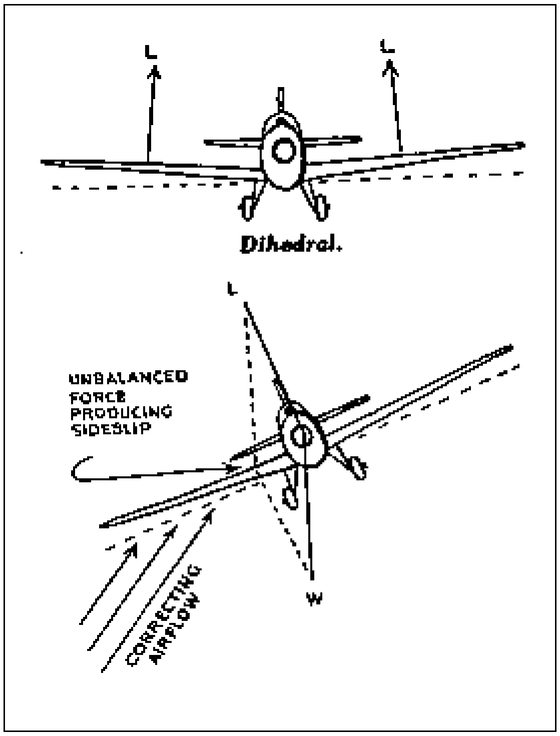

Figure 11 Effect of Dihedral

disturbance causes one wing to drop, the unbalanced force produces a sideslip in the direction of the down-going wing. This will, in effect, cause a flow of air in the opposite direction to the slip, and will meet the lower wing at a greater angle of attack than it meets the up-going wing. The relative increase in the lift of the lower wing will cause the airplane to roll back to the upright position.

Directional Stability

Directional Stability is **Yaw Stability** or stability around the Vertical Axis.

The most important feature that affects directional stability is the vertical tail surface, the fin and rudder. Because of the vertical tail surface, and to some extent the vertical side areas of the fuselage, an airplane has the tendency to always fly head-on into the relative wind. This is described as wind-vaning. If the airplane yaws away from its flight path, the airflow strikes the vertical tail surface from the side and forces it back to its original line of flight.

Flight Performance

Torque

The propeller usually rotates clockwise, when viewed from behind the airplane. The reaction to the spinning propeller causes the airplane to rotate counter-clockwise, or roll to the left. This left rolling tendency is known as Torque.

On **take-off**, torque affects directional control as it results in a tendency to turn **Left**. Use of **Right Rudder** during the take-off roll corrects this condition.

Asymmetric Thrust

At high angles of attack and high power settings, such as during take-off, the descending blade of the propeller has a greater angle of attack than the ascending blade. With more lift being created on the right side of the propeller, as seen from behind the airplane, a yawing tendency to the Left occurs. In level flight, both blades of the propeller meet the relative wind equally and produce equal lift or thrust.

On **take-off**, the tendency for the airplane to turn **Left** is corrected by the use of **Right Rudder**.

Precession

The spinning propeller of an airplane acts like a gyroscope. A characteristic of a gyroscope is rigidity in space, ie., the rotating gyro tends to stay in the same plane of rotation and resists any change in that plane.

If forced to change, Precession takes place. Application of a force at a point in the plane of rotation results in movement of the plane in a direction 90 degrees removed from the point of application, in the direction of rotation of the gyro.

When an airplane pitches Nose-Down, such as when a tail-wheel configured airplane has its tail raised during **take-off**, the application of the pitching force can be considered to be at the top of the plane of rotation of the propeller. Using the principle of precession, the resultant force is applied on the Right side, as seen from behind the airplane, of the propeller plane. This causes a yawing tendency to the **Left**, which is corrected by use of **Right Rudder**.

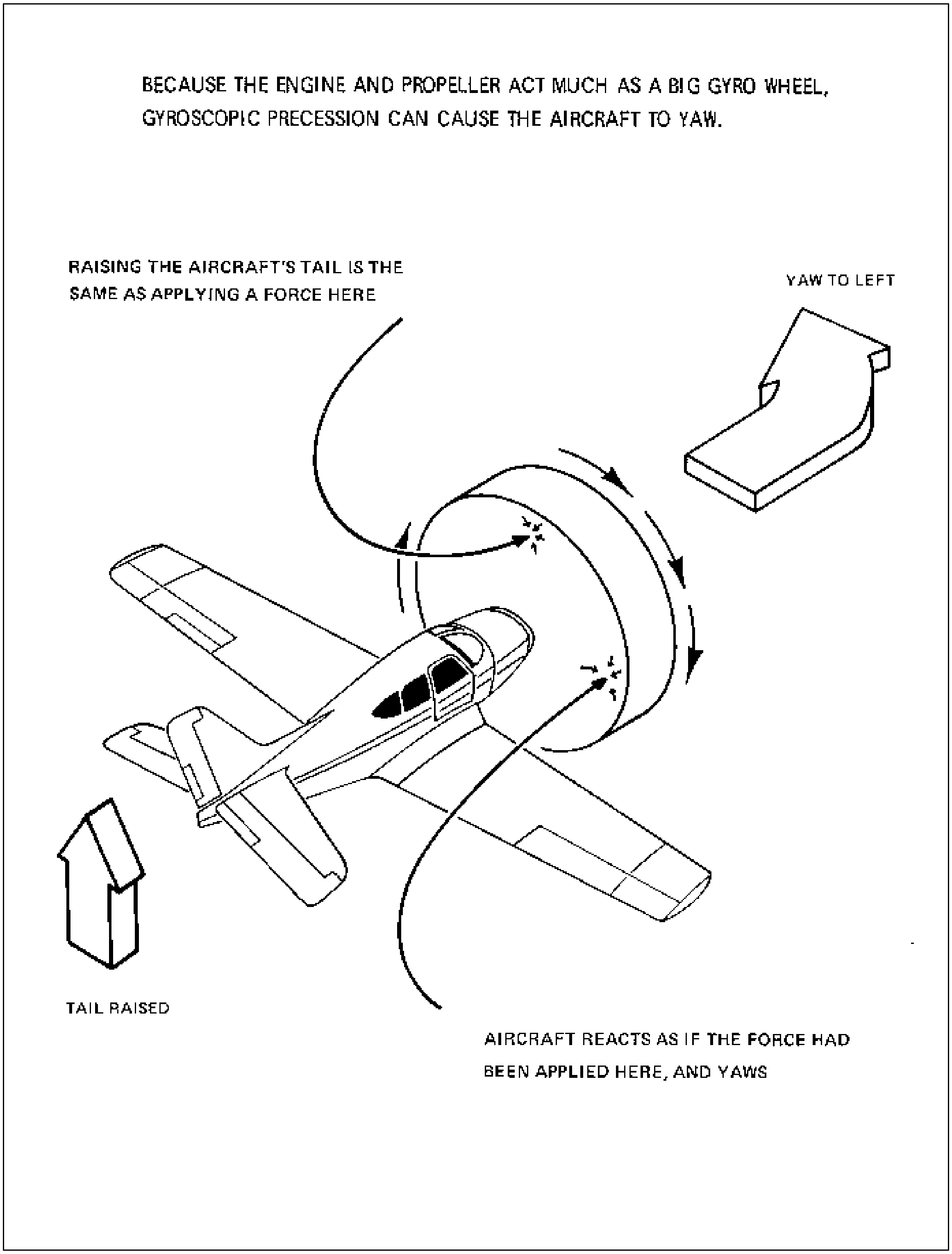

Figure 12 Gyroscopic Precession

Slipstream

The air pushed backward by a revolving propeller has a corkscrew motion. This causes an increased pressure on one side of the tail unit, and a decrease in pressure on the other side. The tail of the airplane is consequently pushed sideways from the high pressure side to the low pressure side – causing the airplane to yaw.

This slipstream effect causes an airplane, especially a tail-wheel configured airplane, as the throttle is opened to commence the **take-off** roll, to yaw to the **Left**. This condition is corrected by using **Right Rudder**. As airspeed increases, this tendency is less pronounced.

Turns

To make an airplane turn, the wings are rolled away from the normal horizontal position of level flight. The lift force, which always acts at 90 degrees to the wingspan, is, in a turn, inclined away from the vertical. Therefore, the vertical forces of lift and weight are no longer in equilibrium. The airplane will descend unless the angle of attack is increased to produce more lift.

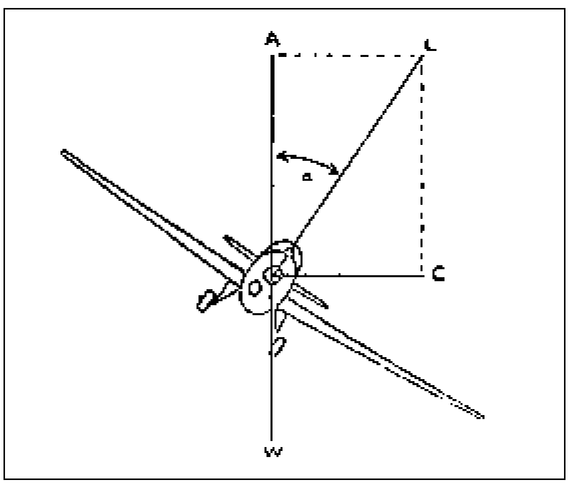

Figure 13 Forces Acting in a Turn

In a turn, the lift force has two components; one acting vertically and one acting horizontally. The vertical component opposes weight, while the horizontal component makes the airplane turn. This force is known as Centripetal Force and reacts to the Centrifugal Force which tends to pull the airplane to the outside of the turn. The steeper the angle of bank, the more total lift is required to produce a level turn. This is achieved by increasing the angle of attack by Aft pressure on the elevator control stick.

The steeper the angle of bank for a given airspeed – the greater the rate of turn, the less the radius of turn, the higher the stalling speed, the greater the loading.

The higher the airspeed for a given angle of bank – the slower the rate of turn, the larger the radius of turn.

Stall

The airfoil stalls when the angle of attack is increased to the point where the streamlined flow if air is unable to follow the upper camber, or curve, of the airfoil. The airflow separates from the wing, with the result that it is not able to create sufficient lift to maintain flight. This is called the **"stall condition**", and the angle of attack at which this occurs is known as the **"stalling angle**". The stalling angle is commonly in the vicinity of 20 degrees, but varies with the shape of the airfoil.

An airfoil will stall at any airspeed if the critical stalling angle is exceeded.

Because insufficient lift is being generated by the wings to maintain flight, a stalled airplane starts to lose altitude. To recover from a stall, the pilot can either lower the nose to decrease the angle of attack, or apply more power to accelerate the airplane.

Spinning

When a wing is stalled, an increase in angle of attack will result in even less lift being created. If rudder is applied to produce a yaw, or a disturbance causes a stalled airplane to drop a wing, the down-going wing will have a greater angle of attack to the relative wind, will generate even less lift, and will tend to drop more rapidly.

The up-going wing will have a lesser angle of attack, will generate more lift, and will tend to rise more rapidly.

The net effect is to accelerate the rolling motion in the direction in which it first started. This is known as **Spinning,** or **Auto–Rotation**.

Any attempt to correct a spin with aileron will only aggravate the roll. If the aileron on the down-going wing is moved downward to bring the wing up, it will meet the airflow at a higher angle of attack and will, therefore, become more stalled that the wing itself. The up-going aileron will be unstalled and will actually augment the lift of the up-going wing.

To recover from a spin, roll should be corrected by the use of opposite rudder, not aileron. To fully recover, use of elevators to pitch the nose down and decrease the angle of attack of the wings is required.